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Acoustic Backscatter of Herring along the West Coast of Newfoundland (NAFO Division 4R) in November from 1989 to 1993

by

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Abstract

In 1989, the first hydroacoustic survey of 4R herring was conducted to develop a fishery-independent relative index of stock abundance. The results from the 1989, 1991 and 1993 fall hydroacoustic surveys are described. Survey results revealed that areas of herring concentrations vary from year to year within the survey area, both in intensity and expanse. Large herring schools were present in the northern strata in 1989. All surveys showed important abundances of herring in the Bonne Bay/Bay of Islands area, although they were much more spread out in 1993. Few herring were seen in the southern strata, i.e. St. George's Bay and Port-au-Port Bay in the years that these strata were surveyed (1989 and 1993). These distributions showed good agreement with the commercial fishing data. Technical problems prevented the reliable estimate of stock biomass from the 1989 survey, although distributional information was obtained. The total biomass estimate in 1991 indicated the presence of approximately 127,000 t of herring in 4R (70,000 t of spring spawners and 57,000 t of autumn spawners). The majority were concentrated around Bonne Bay. In 1993, the total biomass estimate was 66,000 t (31,000 t of spring spawners and 35,000 t of autumn spawners). These herring were much more dispersed than in 1991. The significant reduction in the biomass estimate between 1991 and 1993 is most likely due to two problems encountered during the 1993 survey: (1) according to commercial fishing logbooks, significant amounts of herring were known to be present in at least one of the un-surveyed strata at the northern end of the survey area and (2) software problems caused the loss of herring backscatter at the ends of numerous transects.

Résumé

En 1989, le premier relevé hydroacoustique du hareng de 4R fut conduit afin de développer un indice relatif de l'abondance du stock indépendant de la pêcherie. Les résultats des relevés acoustiques d'automne de 1989, 1991 et 1993 sont décrits. Les résultats des relevés révèlent que les aires de concentrations du hareng varient d'année en année à l'intérieur de la zone du relevé, à la fois en intensité et en étendu. De grands bancs de hareng furent présents dans la strate du nord en 1989. Tous les relevés démontrent l'abondance importante du hareng dans les régions de Bonne Bay et Baie des Iles. Peu de hareng furent aperçus dans une strate du sud, c'est-à-dire aux Baies St-Georges et Port-au-Port aux années où les strates furent échosondées (1989 et 1993). Ces distributions démontrent une bonne concordance avec les données de pêche commerciale. Lors du relevé de 1989, des problèmes techniques ont empêché une estimation fiable de la biomasse du stock, quoique de l'information sur la distribution fut obtenue. L'estimation de la biomasse totale de 1991 indique la présence d'environ 127,000 t de hareng dans 4R (70,000 t de frayeurs de printemps et 57,000 t d'automne). La majorité était concentrée autour de Bonne Bay. En 1993, l'estimation de biomasse totale était de 66,000 t (31,000 t de frayeurs de printemps et 35,000 t d'automne). Ces harengs étaient plus éparses qu'en 1991. La réduction significative dans l'estimation de biomasse entre 1991 et 1993 est le plus probablement due à deux problèmes survenus durant le relevé de 1993: (1) selon les données des journaux de bord des pêcheurs commerciaux, des quantités significatives de hareng étaient présentes dans au moins une des strates non-sondées de l'extrémité nord de l'aire du relevé et (2) des problèmes de logiciel ont causé la perte d'échos de hareng à la fin de nombreux transects.

Introduction

Abundance indices have been routinely estimated for the spring- and autumn-spawning herring stocks in NAFO division 4R from commercial gillnet data and index fisherman logbooks (McQuinn and Lefebvre 1993). Extensive analyses have been performed on these data to remove certain biases (McQuinn 1987) and to standardize them for multiplicative effects such as fishing area and season (Gavaris 1980). However, the reliability of the resulting catch rates as indicators of stock abundance is limited due to their restricted geographic coverage and other biases which are presently unaccounted for. Other catch and effort data are available from the purse seine fishery, however catch rates from purse seines are difficult to interpret and do not appear to follow abundance trends (Powles 1981).

Doubts about the reliability of the commercial gillnet data and even about the future of the gillnet fishery in western Newfoundland underlined the need to develop an index independent of the fishery to follow trends in stock abundance. Traditional research trawl surveys, such as those for groundfish based on catch per tow, are not suitable for highly-gregarious pelagic species such as herring, where the entire water column must be sampled. Over the past few decades, hydroacoustic technology has become a popular tool for surveying fish stocks, and particularly pelagic species, and hydroacoustic surveys have been conducted on herring stocks in eastern Canada since the early 1980's (Shotton and Randall 1982, Buerkle 1985). This technology overcomes a major limitation of trawl surveys by enabling the surveyor to sample the entire pelagic zone rather than only the height of the trawl opening, which is essential for estimating the abundance of pelagic species.

In 1989, the Quebec Region of Fisheries and Oceans embarked on a program of hydroacoustic surveys for pelagic fish stocks. The short term objective of the program was to acquire the necessary equipment and competence to conduct such surveys. The medium term goal was to develop a fishery-independent relative index of stock abundance for the 4R herring, including other stocks as the techniques and resources improved. This document summarizes the results from the 1989 to 1993 4R herring hydroacoustic research surveys.

Study Area and Fish Distribution

The west coast of Newfoundland is characterized by a long (800 km), straight coastline with a few, relatively large bays, i.e. St. George's Bay, Port-au-Port Bay, Bay of Islands, Bonne Bay and St. John's Bay (Figure 1). Historical fishing patterns suggest that in the late fall/early winter, the herring move to the nearshore to concentrate in dense schools in and around several of these bays. In 1982 and from 1984 to 1987 observers aboard two of the commercial purse seiners recorded the areas searched for herring, positions where herring schools were observed and the locations of successful sets from October through December (Figure 2-4). These data suggested that during this period, large, relatively stationary herring schools concentrated nearshore (approximately within the 100 m isobath) around the Bay of Islands, Bonne Bay and occasionally in St. John's Bay. Other concentrations may also exist along the coast in areas which were not searched i.e. St. Georges Bay, although presumably these too would be within the 100 m depth contour at this time of year. The relatively even coastline, along with the apparently stable distribution of herring schools in the late fall, made the west coast of Newfoundland a promising location for conducting acoustic surveys.

Material and Methods

The 1989 Survey

This survey was conducted from November 15 to December 3 aboard the R/V *E.E. Prince* (P392). The hydroacoustic equipment used for this survey was a DATASONICS DFT-210 multi-frequency, 2 channel scientific transceiver connected to a DATASONICS 120 single-beam transducer. This transducer was calibrated using a hydrophone at the Defence Research Establishment Atlantic (DREA) in July, 1987 and again in August, 1991 (Table 1a). The resonant frequency of this transducer was determined to be 112.2 kHz, therefore the DATASONICS was adjusted to this frequency for the calibrations and for conducting the survey. It was later determined that this change in resonant frequency from 120 to 112.2 kHz was due to one or more bad elements in the transducer. Further to this problem, the two calibrations conducted in 1987 and 1991 did not yield similar measurements for the source level and receive sensitivity. Due to the poor performance of the transducer and the incertitude as to the proper calibration parameters, the data from this survey has been analysed only as a relative measure of abundance between strata and for distributional information.

The two channels of the echosounder were adjusted for TVG functions of 100 and 200 m, respectively. Several TVG calibrations were conducted before and during the survey following the procedures of Buerkle (1984). When adjustments were made to the input attenuation, the bandwidth or the TVG function itself, the TVG was recalibrated (Table 2).

During the survey, analog echo signals were digitized by a SIMRAD QX525 A/D converter and stored on disk in real-time by the FEMTO hydroacoustic data processing system (HDPS model J8618), all generously loaned to us by Dr. Udo Buerkle at the St. Andrews Biological Station (SABS). The raw analog signal was also stored on digital audio tape (DAT) as a backup.

The transducer was deployed over the starboard side of the vessel in a winged tow-fish. Tow-fish stability (pitch and roll) were measured continuously with potentiometers installed in the towed body. Although pitch was found to be relatively stable (±2° C), roll was found to vary considerably (±10° C) depending on conditions such as current and swell. Cable length and vessel speed (from 5-8 knots) were therefore adjusted to restrain the roll of the towed-body to < 5° C.

The survey was intended to cover the entire west coast of Newfoundland from Cape Ray to the northern end of the Strait of Belle Isle approximately within the 10 m and 100 m isobaths (7800 km^2). The survey design was a stratified-random sample of parallel transects as suggested by Jolly and Hampton (1987) and as recommended by the CAFSAC Pelagic subcommittee (O'Boyle and Atkinson 1989). The stratification allowed an intensification of sampling effort and a reduction of the variance of the population estimate in those strata where herring were most likely to be encountered. The survey area was stratified based in the major physical features along the coastline and from data on known herring concentrations obtained from the observer data for November (Figure 3).

The orientation of the transects within each stratum was determined by drawing a baseline parallel to the coastline and selecting transects perpendicular to the line. The transects were then chosen by dividing the baseline into 200 m wide units, and selecting randomly among the units (Figure 5). The strata were rated either 1 or 2 according to the proposed sampling intensity, strata with a rating of 1 having twice the sampling intensity of strata with a 2 rating. The higher sampling intensity was given to strata where herring were known to concentrate from Figure 3 and from fishermen's reports. The total number of transects was determined by the available ship time minus 30% for down-time (poor weather, equipment failure, etc.). Surveying was conducted 24 h per day. Due to insufficient vessel time, frequent bad weather and equipment adjustments and the slow speed required to keep the tow-fish level, not all strata were covered (Figure 5).

Biological sampling of observed schools has often been the weak point of herring acoustic surveys (Shotton and Randall, 1982, Wheeler 1991), and this survey was no exception. Of the 9 sets attempted by the R/V *E.E. Prince* with an Engel midwater trawl (EMT), only 4 sets captured more than 50 herring (Table 3). However, biological information was augmented in stratum 5 by a sample obtained from a purse seiner operating in the same area at the same time as our survey.

The 1990 Survey

The 1990 survey was conducted on the CSS *Alfred Needler* (N145) from November 20 to December 4. The transceiver and transducer were the same as in 1989, although the tow-fish was a FATHOM torpedo type and a longer cable was used. Data acquisition was achieved using a FEMTO HDPS J9001 system for digitization and storage.

Transects were determined using the same methodology as in 1989 although the number and size of strata, as well as the sampling intensity were modified according to the distribution of the herring schools from the previous years' survey. Unlike the previous year, all strata were covered although surveying was conducted only during night-time hours (~15:00-07:00) to avoid differences in target strength between day and night (Buerkle 1983, Foote 1987). A juvenile cod survey was conducted during daylight hours with a Western 2A bottom trawl.

During this survey, very few schools were observed, even when surveying in the same areas where the purse seine fleet was operating. Because of differences in both the vessel and the equipment used from the previous year, we were not able to determine with certainty the cause for the lack of significant school detections although two main causes are suspected. It is possible that fish detection was hampered by a poor signal/noise ratio or that the herring were frightened off by the vessel. In the first case, it was noted that acoustic noise was significantly higher than in 1989 and that the received signal was weaker. Although the same transducer was used as in 1989, the 1991 calibration showed a deterioration of the source level between 1987 and 1991 (Table 1b) and, as stated earlier, this transducer was later found to be defective. In addition, the two-way losses for the longer cable used in this survey were measured at 5.2 dB.

Typically, herring schools are very dense at this time of the year and should be easily detectable in spite of the poorer S/N ratio. Indeed, some herring schools were recorded, showing that fish detection by the acoustic equipment was possible. However, schools were rarely insonified even when surveying in

areas of known dense herring concentrations. In fact, while surveying Bonne Bay Bank on a night where five purse seiners were actively fishing, no herring schools were detected. This led us to suspect that significant vessel noise was causing an avoidance behaviour by the fish. Recent vessel noise measurements conducted by the Department of National Defence (McKeown 1995) gives noise spectra for the CSS *Alfred Needler* close to our survey speed (7 knots). This report showed that the CSS *Alfred Needler* produces noise peaks of over 160 dB within the sensitive frequency spectrum for herring (20 Hz-1200 Hz). This value is 30 dB over the suggested limit of 132 dB for research vessel noise determined by a recent ICES study group and well above the reaction threshold for herring at less than 100 m range (Anon 1994). It is most probable that this vessel simply scared herring away from its path in the relatively shallow waters (<100 m) along western Newfoundland. This problem has been observed with other "noisy" vessels in relation to a variety of species (Anon 1994) including herring (Olsen *et al* 1983, Misund 1990).

Bottom- and midwater-trawl sets during the cod juvenile survey did capture herring at various sites along the coast (Table 3). Length frequencies from these data showed a mixture of adult and juvenile herring. These biological data will be discussed later, however as it was unlikely that the acoustic data from this survey would produce interpretable results, the acoustic data were not analysed.

The 1991 Survey

The 1991 survey was conducted on the R/V *E.E. Prince* (P423) from November 22 to December 1. The hydroacoustic equipment used was essentially the same as in 1990 (e.g. DATASONICS DFT-210 echosounder, J9001 digitizer, DAT recorder), with the exception of the cable, which was the same as in 1989, and a new SIMRAD 120 kHz single beam transducer. The two channels of the echosounder were adjusted for TVG functions of 100 and 200 m, respectively. Several TVG calibrations were conducted before, during and following the survey using the HDPS software and following the procedures of Buerkle (1984). Besides the factory specifications, the transducer was also post-calibrated using a hydrophone at DREA in July 1992 (Table 1b). With this transducer/cable combination, the echo signal was much improved compared with previous years and much more backscatter from herring schools was detected.

The transducer was deployed over the starboard side of the vessel in the FATHOM tow-fish. Tow-fish stability (pitch and roll) were measured continuously with potentiometers. Again pitch was found to be relatively stable (±2° C) although roll was found to vary considerably (±8° C) depending on conditions such as current and swell. Cable length and vessel speed (from 7-10 knots) were therefore adjusted to restrain roll > 5° C.

The survey area and design was the same as in 1990 and was intended to cover the entire west coast of Newfoundland from Cape Anguille to the southern end of the Strait of Belle Isle approximately within the 10 m and 100 m isobaths. Again, surveying was conducted only during night-time hours (17:00-07:00). Due to insufficient allocated vessel time and considerable down-time due to bad weather, not all strata were covered (Figure 6). The missed strata were mainly in the south (strata 1-3) where few herring were observed during the 1989 survey and where no commercial fishery occurs at this time of the year.

Biological sampling aboard the R/V *E.E. Prince* was again inadequate to properly describe the biological characteristics of all the major herring concentrations surveyed acoustically (Table 3). Of the 7 sets attempted on the R/V *E.E. Prince* with an EMT, only 3 captured herring, and of those, only 2 had samples sizes greater than 50 (Table 3). However, as in 1989, biological information was augmented in certain strata by samples obtained from purse seiners operating in the same area at the same time as our survey.

The 1993 Survey

The hydroacoustic work for this survey was conducted from November 10 to November 27 aboard the NSC *Frederick G. Creed* while the STD profiling and biological sampling were carried out aboard the R/V *E.E. Prince*. The echosounder used was the SIMRAD EK500 which powered a 120 kHz hull-mounted, split-beam transducer. The equipment was calibrated both before and after the survey (Table 1c) using a copper sphere of known target strength and following the procedures specified by SIMRAD (SIMRAD EK500 Instruction Manual). The copper sphere was placed in the beam using a computer-controlled motorized positioning system developed at the Maurice Lamontagne Institute (MLI).

The NSC *Frederick G. Creed* proved to be an excellent hydroacoustic platform, both for its stability (pitch= ±2° C; roll= 0° C) and for its surveying speed (12-14 knots). The NSC *Frederick G. Creed* is a small (20 m) aluminum Small Waterplane Area Twin Hull (SWATH) vessel capable of working comfortably in heavy seas (4 m waves). The vessel's small size has the added advantages of generating less vessel noise and of being highly manoeuvrable, thereby facilitating nearshore surveying. In addition to acquiring a superior hydroacoustic platform, having two relatively small vessels to conduct this survey enabled us to use the acoustic survey time much more efficiently, allowing the R/V *E.E. Prince* to concentrate on the oceanographic profiling and biological ground truthing.

Again random-parallel transects were run during night-time hours only (17:00-07:00) covering the same planned strata as in 1990 and 1991. Sampling was increased in strata of suspected high density (5,6,8,10). However, despite having sufficient vessel time allotted for the survey, poor weather conditions (mainly anomalously high winds of 50 to 70 knots and freezing spray) reduced surveying time by 60%. For this reason, the northern strata (9,10) were not surveyed (Figure 7). In addition, herring backscatter was lost from several files due to a problem with the logging software which was detected half way through the survey. Unfortunately, as there is no analog signal output by the EK500, no DAT backup recording was made. The effects of this data loss on the biomass estimate will be discussed later.

Given the rather poor biological sampling results during previous surveys, several measures were taken to improve the pelagic fishing capabilities of the R/V *E.E. Prince*. A pelagic mackerel trawl (MT) designed for MLI for use on a small (20 m) vessel was installed aboard the R/V *E.E. Prince* and several practice sets were made before surveying began. We were also equipped with a Scanmar Sonar System on the trawl, and had an experienced fishing master aboard. The fishing master and this improved equipment allowed us to significantly increase our sampling success and most of the major concentrations of herring were adequately sampled (Figure 7, Table 3).

Data Analyses

Data treatment and analysis was standard for all surveys. Recorded echo signals were edited using the FEMTO HDPS software to eliminate backscatter other than herring schools (e.g. surface noise, bottom signal, other species). The species composition of some schools was unconfirmed by biological sampling because we were unable to catch them with the research vessel or there was no fishing activity in the area. In these cases, gross form and density were considered to judge whether or not they were to be included in the analyses. Most fish schools recorded were considered to be herring. Herring schools at this time of the year show a relatively limited range of characteristic shapes, from candle shaped, to dense domes on the bottom, to large aggregations 10's of meters thick.

Estimates of area backscatter and biomass were calculated following the procedures of Buerkle (1990) and as recommended by CAFSAC (O'Boyle and Atkinson 1989). The conversion of backscatter to biomass was accomplished using target strength estimates per unit length determined from the equation suggested by Foote (1987) for clupeoids:

$$TS_{cm} = 20 \log l - 71.9 \qquad (1)$$

where l is the mean total fish length (cm), and converting to target strength per unit weight:

$$TS_{kg} = TS_{cm} + 10 \log w^{-1}$$

where w is the mean weight of an individual (kg). The mean lengths and weights were calculated for each transect from the samples most closely associated with each school. Total biomass of spring and autumn spawners was calculated using an estimate of the percent weight of each spawning stock corresponding to each sample (Table 4).

Equation 1 is a general algorithm applicable for all clupeoids but does not consider the effects of several factors such as fish behaviour (e.g. tilt angle), physiology and depth on the parameters (Ona 1990). As such, the TS values estimated from this equation should be considered as approximations. Although certain measures were taken to reduce interannual variability in TS, i.e. surveying at night only, there may still be inherent biases from the general formula due to the local conditions in 4R which affect the aforementioned factors.

Results

Distribution

The fall 4R herring acoustic surveys conducted in 1989, 1991 and 1993 revealed that areas of herring concentrations vary from year to year within the survey area, both in intensity and expanse (Table 5-7). Although the results of the 1989 survey did not yield useful biomass estimates due to technical problems (Table 8), we were nonetheless able to confirm the presence of large herring schools in the northern strata in that year (Figure 5). All of the surveys showed important abundances of herring in the Bonne Bay/Bay of Islands area (Figures 5-7), although they were much more spread out in 1993 (Figure

7). Few herring were seen in the southern strata, i.e. St. George's Bay and Port-au-Port Bay in the years that these strata were surveyed (1989 and 1993). These distributions are in good agreement with the observer data (Figure 3) which showed herring mainly concentrated in the Bonne Bay/Bay of Islands area with some schools found towards the northern peninsula.

Size Composition

Several patterns can be discerned from the length frequency data collected from these surveys. The large 1987 spring-spawning and 1986 autumn-spawning year-classes were observed in St. John's Bay (4Ra) in 1989 as 2 and 3 year-olds, respectively, but only appeared in the Bonne Bay area (4Rb) a year later as mature 3 and 4 year-olds (Figures 8 and 9). These have been the dominant year-classes for their respective stocks since then. The 1989 spring-spawning year class was also poorly represented in 4Rb at age 2 in 1991 and at age 4 in 1993, but was a strong component in 4Rc in (Figure 8).

The autumn-spawning size composition suggests that the 1988 and 1990 year-classes have shown good recruitment to the Bonne Bay area over the past four years, although the relative strength of each has varied from year to year (Figure 9). In particular, the 1988 year-class appeared promising at age 2 in 1990, less so in 1991, but was a strong component of the 1993 survey in both 4Rb and 4Rc. Although the samples from 4Ra and 4Rc are admittedly limited, the data also suggests a segregation according to size between Bonne Bay, St. John's Bay and Bay of Islands (4Rc), the older individuals being found mainly in Bonne Bay. This interannual and interzonal variability in relative year-class strength suggests a substructure among areas which may be related to the interannual variability seen in their distribution (Figures 5-7).

Abundance

The total biomass estimate indicated the presence of approximately 127,000 t of herring in 4R in 1991 (70,000 t of spring spawners and 57,000 of autumn spawners), with 96% being found in strata 6 and 8 (Table 9). These herring were thus highly concentrated around Bonne Bay and appeared to be quite stationary as the purse seine fleet continued to fish in this area until mid-December.

In 1993, the total biomass estimate was 66,000 t, of which 31,000 t were spring spawners and 35,000 t were autumn spawners (Table 10). The herring in the Bonne Bay area were much more dispersed in 1993, and were apparently on the move, as they had left the area a week after our survey. This represents a significant reduction in the biomass estimate from two years previous. However, the 1993 estimate must be considered an underestimate for several reasons. Firstly, fishing was taking place in the northern, un-surveyed strata, confirming the presence of additional herring schools in these areas, as in 1989 (Figure 5). Secondly, as mentioned earlier, software problems caused the loss of herring backscatter at the ends of numerous transects during this survey. In particular, the density estimates for strata 5 and 6 where the majority of herring were seen were affected in this way. For these reasons, the 1993 biomass estimate is biased downward and is not directly comparable to the 1991 estimate, although at least 66,000 t of spring and autumn spawners were estimated in the southern strata.

Discussion

Results from the surveys conducted in 1989, 1991 and 1993 showed some variability in the distribution of herring acoustic backscatter between years, although the range in distribution appears to be at least within the study area. No herring schools have been detected during several exploratory transects conducted outside the study area, particularly in deeper waters. Continued exploration outside the survey area will remain an important measure to insure that the bulk of the stock complex is being assessed.

Size composition data showed that recruiting year-classes eventually congregate in the Bonne Bay/Bay of Islands area from October to December, where they become the object (along with older year-classes) of the traditional purse seine fishery. With the approach of winter, these schools migrate out of this area into the deeper waters of the Esquiman Channel (McQuinn and Lefebvre 1995). The October-December period thus appears to be the best time to survey these stocks. Generally, these herring schools are relatively stable and predictable, as witnessed by both the fishery and acoustic survey data. Surveying difficulties are generally related to operating too late in the year, when windy and icy weather conditions reduce efficiency. Moving the survey to October will alleviate many of these problems, although the timing of the arrival of these schools in the nearshore area then becomes an important factor (Figure 2).

The 1991 survey produced the most reliable biomass estimate, although before this value can be considered in absolute terms, confirmation of its accuracy must be made by other means (i.e. from fishery related data or future acoustic surveys). The value of 127,000 t in 1991 seems reasonable as a total biomass estimate for these stocks although insufficient biological sampling, some un-surveyed strata, as well as assumptions associated with the TS values used adds uncertainty to the estimate. An evaluation of 66,000 t of herring in 1993 should be considered a minimum estimate given the aforementioned caveats concerning the known biases in this survey.

Since the first 4R herring acoustic survey in 1989, there has been a considerable evolution in both the equipment used for these surveys as well as our ability to conduct them. Our lack of experience in the early years prevented the generation of reliable biomass estimates from the 1989 and 1990 surveys, although useful data on herring distribution and school composition was collected. An expansion in the use of hydroacoustics at MLI along with our technical expertise has allowed us to development many more hardware and software tools which should considerably increase the reliability of future surveys. Measures have been taken for the 1995 survey to avoid the problems encountered in previous years. The most important areas of improvement are the timing of the survey (see above), and concerning our ability to catch relatively small schools with a pelagic trawl, as well as the reliability and precision of data acquisition. A co-operative research project has been proposed with industry to acquire the use of a commercial pelagic trawler for the collection of biological samples. In addition, a PC-based software package developed at MLI will also be used for data storage allowing a more complete exploitation of the EK500 data output.

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References

Anon. 1994. Report of the study group on research vessel noise measurements. ICES Fish Capture Comm. C.M. 1994/B:5

Buerkle, U. 1983. First look at herring distributions with a bottom referencing underwater towed instrumentation vehicle: "BRUTIV". *In* Nakken, O. and Venema, S.C. *eds.* Symp. Fish. Acoust., Bergen, Norway. FAO Fish. Rep. 300:125-130.

Buerkle, U. 1984. Calibration of time-varied gain echosounder receivers. Can. Tech. Rpt. Fish. Aquat. Sci. 1298: iii+6 p.

Buerkle, U. 1985. Acoustic estimation of fish abundance in a large aggregation of herring. CAFSAC Res. Doc. 85/62, 26 pp.

Buerkle, U. 1990. Results of the 1990 winter acoustic surveys of NAFO div. 4WX stocks. CAFSAC Res. Doc. 90/67, 22 pp.

Foote, K.G. 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am. 82:981-987.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can J. Fish. Aquat. Sci. 37:2272-2275.

Jolly, G.M. and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Can. J. Fish. Aquat. Sci. 47 (7):1282-1291.

McKeown, D.L. 1995. Ambient acoustic noise: CSS Alfred Needler. Bedford Institute of Oceanography, Dartmouth, N.S., Canada.

McQuinn, I.H. 1987. A re-evaluation of the west coast of Newfoundland herring resource (NAFO division 4R). CAFSAC Res. Doc. 87/67, 37 p.

McQuinn, I.H. and L. Lefebvre. 1993. An assessment of the west coast of Newfoundland (NAFO division 4R) herring Resource up to 1992. DFO Atl. Fish. Res. Doc. 93/53, 48 p.

McQuinn, I.H. and L. Lefebvre. 1995. Distribution, movements and size composition of spring-spawning herring in the northern Gulf of St. Lawrence . DFO Atl. Fish. Res. Doc. 95/57, 31 p.

Misund, O.A. 1990. Sonar observations of schooling herring: school dimensions, swimming behaviour and avoidance of vessel and purse seine. Rapp. P.-v. Réun. Cons. int. Explor. Mer. 189:135-146.

O'Boyle, R.N. and D.B. Atkinson. 1989. Hydroacoustic survey methodologies for pelagic fish as recommended by CAFSAC. CAFSAC Res. Doc. 89/84, 40 pp.

Olsen, K., J. Angell, F. Pettersen and A. Lovik. 1983. Observed fish reactions to a surveying vessel with special reference to herring, cod, capelin and polar fish. *In* Nakken, O. and Venema, S.C. *eds.* Symp. Fish. Acoust., Bergen, Norway. FAO Fish. Rep. 300:131-138.

Ona, E. 1990. Physiological factors causing natural variations in acoustic target strength of fish. J. mar. biol. Ass. U.K. 70:107-127.

Powles, H. 1981. What does a purse seine catch per unit effort measure? A simple fishery model. CAFSAC Res. Doc. 81/36, 27 p.

Shotton, R. and R.G. Randall. 1982. Results of acoustic surveys of the Southwest Nova Scotia (NAFO division 4WX) herring stock during February and July, 1981. CAFSAC Res. Doc. 82/44, 29 pp.

Wheeler, J.P. 1991. Newfoundland East Coast herring - 1990 acoustic survey results. CAFSAC Res. Doc. 91/1, 43 p.

Table 1a. Specifications for the DATASONICS 120 kHz single-beam tranducer from DREA hydrophone calibrations conducted in 1987 and 1991 (parameter estimates in **bold** were used in the analyses).

Parameter	1987	1991
-3 dB Beam Width (deg):	**6.0**	6.0
Directivity Index (dB):	**29.6**	29.6
Equivalent 2-way beam angle (dB):	**-22.07**	-22.62
Transmitting Response (dB re 1 μPa/A):		
- (112.2 kHz)	208.6	208.5
Source Level (dB re 1 μPa):		
- (120 kHz)		
a) Full power:	-	210.3
b) -10 dB:	-	202.5
- (112.2 kHz)		
a) Full power:	222.2	217.5
b) -10 dB:	-	**209.7**
Receiving Sensitivity (dB re 1 V/μPa):		
- (112.2 kHz)	**-189.6**	-184.6

Table 1b. Specifications for the SIMRAD 120 kHz single-beam tranducer from factory calibration conducted in August 1991 and from DREA hydrophone calibration conducted in July 1992 (parameter estimates in **bold** were used in the analyses; doubtful estimates are in *italics*).

Parameter	SIMRAD	DREA
-3 dB Beam Width (deg):	**9.5**	9.5
Directivity Index (dB):	**25.6**	25.7
Equivalent 2-way beam angle (dB):	**-18.1**	-18.1
Transmitting Response:		
- (dB re 1 μPa/V)	177.0	176.5
- (dB re 1 μPa/A)	213.2	*211.0*
Source Level:		
- measured (dB re 1 μPa)	-	*222.5*
- estimated (a) dB re 1 μPa/V	**225.1**	224.6
(b) dB re 1 μPa/A	225.1	*222.9*
Receiving Sensitivity (dB re 1 V/μPa):		
- loaded	-	**-183.3**
- unloaded	-182.4	-182.7

Table 1c. Specifications for the SIMRAD 120 kHz split-beam tranducer from target-sphere calibrations conducted before and after the 1993 survey (parameter estimates in **bold** were used in the analyses).

Parameter	11/11/93	28/11/93
-3 dB Beam Width (deg):	**7.4**	-
- Longitudinal offset	**0.04**	-
- Transversal offset	**0.03**	-
Directivity Index (dB):	**28.1**	28.1
Equivalent 2-way beam angle (dB):	**-20.2**	-20.2
Transmitting Response:		
- (dB re 1 μPa/V)	184.3	184.3
- (dB re 1 μPa/A)	209.7	209.7
Receiving Sensitivity (dB re 1 V/μPa):		
- unloaded	-186.0	-186.0
Transceiver Gain (dB):		
- 20 log r	**25.0**	25.1
- 40 log r	25.2	25.0

Table 2. TVG calibration parameters for various settings used in 1989 herring acoustic survey.

Model fitting results for: C392010 (14/11/89)

Independent variable	coefficient	std. error	t-value	sig.level
Fixed Gain	-35.953881	0.533161	-67.4353	0.0000
Log Coefficient	-22.104176	0.561582	-39.3605	0.0000
Alpha Coefficient	-0.067223	0.00172	-39.0916	0.0000
Linearity	1.116066	0.008155	136.8553	0.0000

R-SQ. (ADJ.) = 0.9988 SE= 0.262518 MAE= 0.197334 DurbWat= 1.095

138 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Model fitting results for: C392018 (17/11/89)

Independent variable	coefficient	std. error	t-value	sig.level
Fixed Gain	-66.382979	0.165756	-400.4868	0.0000
Log Coefficient	-15.176252	0.283651	-53.5032	0.0000
Alpha Coefficient	-0.076966	0.002037	-37.7757	0.0000
Linearity	1.083575	0.004419	245.1921	0.0000

R-SQ. (ADJ.) = 0.9989 SE= 0.207989 MAE= 0.152990 DurbWat= 1.052

108 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Model fitting results for: C392026 (20/11/89)

Independent variable	coefficient	std. error	t-value	sig.level
Fixed Gain	-52.168959	0.31244	-166.9725	0.0000
Log Coefficient	-21.790533	0.453176	-48.0841	0.0000
Alpha Coefficient	-0.038176	0.002515	-15.1787	0.0000
Linearity	1.06864	0.01146	93.2497	0.0000

R-SQ. (ADJ.) = 0.9978 SE= 0.325100 MAE= 0.230536 DurbWat= 1.255

103 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Model fitting results for: C392032 (22/11/89)

Independent variable	coefficient	std. error	t-value	sig.level
Fixed Gain	-62.317467	0.185255	-336.3870	0.0000
Log Coefficient	-21.279318	0.314517	-67.6571	0.0000
Alpha Coefficient	-0.051314	0.002237	-22.9365	0.0000
Linearity	1.071155	0.004743	225.8256	0.0000

R-SQ. (ADJ.) = 0.9989 SE= 0.210932 MAE= 0.161638 DurbWat= 1.225

108 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

Table 3. Date, gear type, stratum, set number, sample number, position and sample size of biological samples from the 4R herring acoustic surveys from 1989 to 1993.

Survey	Date	Gear	Stratum	Set	Sample #	Position	N
P392 (1989)	171189	EMT	2	1	500001	482841 582841	32
	171189			2	500002	483025 583375	149
	251189		5	2	500004	493500 580000	115
	021289			1	500008	483500 584450	6
	261189	Seine		S	544038	493500 580100	144
	251189	EMT	7	1	500003	493350 575650	67
	261189		8	1	500005	502290 573600	10
	271189		9	1	500006	504300 572600	23
	271189			1-2	500007	505120 571500	96
N145 (1990)	031290	EMT	1	P24		482790 583240	1
	031290	Western 2A	2	38	500042	482600 585020	10
	031290			39	500043	482760 585550	50
	021290		3	35	500041	484300 591420	32
	021290			36	500049	483910 590780	1
	021290		4	32	500040	484240 585260	10
	011290			P02	500050	484100 584300	65
	231190		6	7	500033	494490 580620	16
	231190			10	500034	493650 581290	3
	301190			25	500038	500260 574820	1
	011290	EMT		P23	500039	493220 580520	232
	261190	Western 2A	9	18	500036	502000 573500	177
	301190			24	500037	500490 574620	1
	261190		10	16	500035	503310 572610	20
	261190			17	500046	500250 572800	2
	281190			19	500047	510780 570360	1
	291190			22	500048	511520 565550	2
P423 (1991)	241191	EMT	5	2	500004	491914 582700	2
	241191			3	-	493183 575542	0
	301191		6	5	500003	493713 580205	243
	241191	Seine		S	544018	GO72	186
	231191	EMT	7	1	-	490922 581434	0
	261191		8	4	500002	493111 575488	52
	011291	Seine		S	544020	GO73	175
C452 (1993)	121193	MT	5	1	500054	492300 582250	46
	121193			2	500055	492290 582270	108
	121193		6	3	500056	492870 581440	284
	141193	EMT		4	500057	493780 580090	42
	141193	MT		5	500058	493920 580000	253
	151193			6	500059	495630 575100	274

Table 4. Percent spring spawners (by weight) from the biological samples collected during the 1991 and 1993 4R herring acoustic surveys.

Survey	Sample Number	% Spring Spawners
P423 (1991)	2	66.2
	3/18	55.0
C452 (1993)	54/55	49.7
	56	66.1
	57/58	44.0
	59	43.1

Table 5. Backscatter and biomass per transect for P392 (1989).

Stratum	Transect Number	Transect Length (m)	Transect Area (km²)	Target Strength (dB/kg)	Sa - Area Scattering (/sr)	Total Scattering (m²/sr)	Biomass Density (Kg/m³)	Total Biomass (t/trans)	Sample Number
ST1	2	3705	37.76	-32.9	0.000000	0	0.0000	0.000	
	3	8967	91.39	-32.9	0.000000	0	0.0000	0.000	
Cape	4	8120	82.75	-32.9	0.000000	0	0.0000	0.000	
Anguille	5	8263	84.21	-32.9	0.000000	0	0.0000	0.000	
	6	6778	69.08	-32.9	0.000000	0	0.0000	0.000	
	7	7821	79.71	-32.9	0.000000	0	0.0000	0.000	
ST2	8	7858	27.98	-36.7	0.000000	0	0.0000	0.000	
	9	7449	26.52	-36.7	0.000000	0	0.0000	0.000	
Bay St.	10	10772	38.36	-36.7	0.000000	0	0.0000	0.000	
Georges	11	12036	42.85	-36.7	0.000001	40	0.0043	185.183	1/2
(south)	12	10826	38.54	-36.7	0.000000	0	0.0000	0.000	
	13	11235	40.00	-36.7	0.000000	0	0.0000	0.000	
	14	11745	41.82	-36.7	0.000000	0	0.0000	0.000	
	15	11588	41.26	-36.7	0.000000	0	0.0000	0.000	
	16	11077	39.44	-36.7	0.000000	0	0.0000	0.000	
	17	10788	38.41	-36.7	0.000000	11	0.0013	50.470	1/2
	18	10534	37.51	-36.7	0.000000	0	0.0000	0.000	
	19	11115	39.57	-36.7	0.000000	0	0.0000	0.000	
	20	10943	38.96	-36.7	0.000000	0	0.0000	0.000	
	21	9295	33.10	-36.7	0.000000	0	0.0000	0.000	
	22	11128	39.62	-36.7	0.000000	0	0.0000	0.000	
	23	9652	34.37	-36.7	0.000000	0	0.0000	0.000	
	24	9962	35.47	-36.7	0.000000	0	0.0000	0.000	
	25	9591	34.15	-36.7	0.000000	0	0.0000	0.000	
	26	8608	30.65	-36.7	0.000000	0	0.0000	0.000	
	27	9445	33.63	-36.7	0.000000	0	0.0000	0.000	
	28	9831	35.00	-36.7	0.000000	0	0.0000	0.000	
	29	9071	32.30	-36.7	0.000000	0	0.0000	0.000	
	30	9254	32.95	-36.7	0.000000	0	0.0000	0.000	
	31	8318	29.62	-36.7	0.000000	0	0.0000	0.000	
	32	8500	30.27	-36.7	0.000000	0	0.0000	0.000	
	33	8171	29.09	-36.7	0.000000	0	0.0000	0.000	
	34	8232	29.31	-36.7	0.000000	0	0.0000	0.000	
	35	7736	27.55	-36.7	0.000000	0	0.0000	0.000	
	36	7212	25.68	-36.7	0.000000	0	0.0000	0.000	
	38	7162	25.50	-36.7	0.000000	0	0.0000	0.000	
	39	5018	17.87	-36.7	0.000000	0	0.0000	0.000	
	40	4545	16.18	-36.7	0.000000	0	0.0000	0.000	
	41	4008	14.27	-36.7	0.000000	0	0.0000	0.000	
	42	3838	13.66	-36.7	0.000000	0	0.0000	0.000	
	43	4093	14.57	-36.7	0.000000	0	0.0000	0.000	
	44	3555	12.66	-36.7	0.000000	0	0.0000	0.000	
	45	4716	16.79	-36.7	0.000000	0	0.0000	0.000	
	46	6145	21.88	-36.7	0.000000	0	0.0000	0.000	
ST3	47	2136	4.82	-36.7	0.000000	0	0.0000	0.000	
	48	3886	8.77	-36.7	0.000000	0	0.0000	0.000	
Bay St.	49	7406	16.72	-36.7	0.000000	0	0.0000	0.000	
Georges	50	10529	23.77	-36.7	0.000000	0	0.0000	0.000	
(north)	53	11045	24.93	-36.7	0.000000	0	0.0000	0.000	
	54	14333	32.35	-36.7	0.000000	0	0.0000	0.000	
	57	5461	12.33	-36.7	0.000000	0	0.0000	0.000	
	58	11980	27.04	-36.7	0.000000	0	0.0000	0.000	
	59	11802	26.64	-36.7	0.000000	0	0.0000	0.000	
	62	13989	31.58	-36.7	0.000000	0	0.0000	0.000	
	64	14909	33.65	-36.7	0.000000	0	0.0000	0.000	
	66	15084	34.05	-36.7	0.000000	0	0.0000	0.000	
	68	14385	32.47	-36.7	0.000000	0	0.0000	0.000	
	69	14558	32.86	-36.7	0.000000	0	0.0000	0.000	
	70	14914	33.67	-36.7	0.000000	0	0.0000	0.000	
	198	14968	33.79	-36.7	0.000000	0	0.0000	0.000	
	199	16030	36.18	-36.7	0.000000	0	0.0000	0.000	
	200	15835	35.74	-36.7	0.000000	0	0.0000	0.000	
	201	16063	36.26	-36.7	0.000000	0	0.0000	0.000	
	202	16508	37.26	-36.7	0.000000	0	0.0000	0.000	
	203	16424	37.07	-36.7	0.000000	0	0.0000	0.000	
	204	17213	38.85	-36.7	0.000000	0	0.0000	0.000	
	205	15504	35.00	-36.7	0.000000	0	0.0000	0.000	

* transects where samples were taken

Table 5. (con't).

Stratum	Transect Number	Transect Length (m)	Transect Area (km^2)	Target Strength (dB/kg)	Sa - Area Scattering (/sr)	Total Scattering (m^2/sr)	Biomass Density (Kg/m^3)	Total Biomass (t/trans)	Sample Number
ST5	104	11120	44.06	-36.7	0.000000	4	0.0005	20.343	4/38
	105	9124	36.15	-36.7	0.000000	0	0.0000	0.000	
Port-au-	106	9477	37.55	-36.7	0.000000	0	0.0000	0.000	
Port	107	11462	45.42	-36.7	0.000000	0	0.0000	0.000	
Bay of	108	8152	32.30	-36.7	0.000000	0	0.0000	0.000	
Islands	109	7468	29.59	-36.7	0.000000	0	0.0000	0.000	
(Gulf)	110	4070	16.13	-36.7	0.000000	0	0.0000	0.000	
Bonne Bay	111	14480	57.38	-36.7	0.000000	0	0.0000	0.000	
Bank	112	12360	48.97	-36.7	0.000000	0	0.0000	0.000	
	113	11848	46.95	-36.7	0.000000	0	0.0000	0.000	
	114	13219	52.38	-36.7	0.000000	10	0.0009	46.799	4/38
	115	12537	49.68	-36.7	0.000000	0	0.0000	0.000	
	116	10063	39.87	-36.7	0.000000	0	0.0000	0.000	
	118	8969	35.54	-36.7	0.000000	0	0.0000	0.000	
	120	12242	48.51	-36.7	0.000000	0	0.0000	0.000	
	121	17603	69.75	-36.7	0.000000	0	0.0000	0.000	
	131	7882	31.23	-36.7	0.000000	0	0.0000	0.000	
	132	8391	33.25	-36.7	0.000000	0	0.0000	0.000	
	133	8190	32.45	-36.7	0.000000	0	0.0000	0.000	
	134	8930	35.38	-36.7	0.000000	0	0.0000	0.000	
	135	10059	39.86	-36.7	0.000000	0	0.0000	0.000	
	136	19679	77.98	-36.7	0.000008	659	0.0394	3069.125	* 4/38
	137	17944	71.10	-36.7	0.000003	197	0.0129	917.397	* 4/38
	138	15359	60.86	-36.7	0.000000	0	0.0000	0.000	
	139	10706	42.42	-36.7	0.000000	0	0.0000	0.000	
	140	10853	43.01	-36.7	0.000000	0	0.0000	0.000	
	141	11162	44.23	-36.7	0.000000	0	0.0000	0.000	
	143	4674	18.52	-36.7	0.000000	0	0.0000	0.000	
	144	11590	45.92	-36.7	0.000000	0	0.0000	0.000	
	145	1437	5.70	-36.7	0.000000	0	0.0000	0.000	
	168	12977	51.42	-36.7	0.000000	0	0.0000	0.000	
	169	12969	51.39	-36.7	0.000000	0	0.0000	0.000	
	170	13213	52.35	-36.7	0.000000	0	0.0000	0.000	
	171	14038	55.62	-36.7	0.000000	0	0.0000	0.000	
	173	13240	52.46	-36.7	0.000000	0	0.0000	0.000	
	174	4874	19.31	-36.7	0.000000	0	0.0000	0.000	
	175	4698	18.62	-36.7	0.000000	0	0.0000	0.000	
	176	2392	9.48	-36.7	0.000000	0	0.0000	0.000	
	177	7221	28.61	-36.7	0.000000	0	0.0000	0.000	
	178	3683	14.59	-36.7	0.000000	0	0.0000	0.000	
	179	3567	14.13	-36.7	0.000000	0	0.0000	0.000	
	180	6577	26.06	-36.7	0.000000	0	0.0000	0.000	
	181	7738	30.66	-36.7	0.000000	0	0.0000	0.000	
	182	7471	29.60	-36.7	0.000000	0	0.0000	0.000	
	183	7824	31.00	-36.7	0.000000	0	0.0000	0.000	
	184	7879	31.22	-36.7	0.000000	0	0.0000	0.000	
	185	7487	29.67	-36.7	0.000001	18	0.0027	81.515	4/38
	186	6642	26.32	-36.7	0.000000	4	0.0007	19.183	4/38
	187	3459	13.71	-36.7	0.000000	0	0.0000	0.000	
	188	3982	15.78	-36.7	0.000000	0	0.0000	0.000	
	189	4261	16.88	-36.7	0.000000	0	0.0000	0.000	
	190	2675	10.60	-36.7	0.000000	0	0.0000	0.000	
	191	2483	9.84	-36.7	0.000000	0	0.0000	0.000	
	192	2707	10.72	-36.7	0.000000	0	0.0000	0.000	
	195	2607	10.33	-36.7	0.000000	0	0.0000	0.000	
	196	4584	18.16	-36.7	0.000000	0	0.0000	0.000	
	197	4340	17.20	-36.7	0.000000	0	0.0000	0.000	
	206	4006	15.87	-36.7	0.000000	0	0.0000	0.000	
	207	4624	18.32	-36.7	0.000000	0	0.0000	0.000	
	208	3850	15.26	-36.7	0.000000	0	0.0000	0.000	
	209	4003	15.86	-36.7	0.000000	0	0.0000	0.000	
	210	3849	15.25	-36.7	0.000000	0	0.0000	0.000	
	211	4670	18.50	-36.7	0.000000	0	0.0000	0.000	
	212	5096	20.19	-36.7	0.000000	0	0.0000	0.000	
	213	3860	15.30	-36.7	0.000000	0	0.0000	0.000	
	214	2934	11.63	-36.7	0.000000	0	0.0000	0.000	
	215	2780	11.01	-36.7	0.000000	0	0.0000	0.000	
	216	2162	8.57	-36.7	0.000000	0	0.0000	0.000	
	217	2007	7.95	-36.7	0.000000	0	0.0000	0.000	
	218	2471	9.79	-36.7	0.000000	0	0.0000	0.000	
	219	1081	4.28	-36.7	0.000000	0	0.0000	0.000	
	220	1544	6.12	-36.7	0.000000	0	0.0000	0.000	
	221	2260	8.95	-36.7	0.000000	0	0.0000	0.000	
	222	2471	9.79	-36.7	0.000000	0	0.0000	0.000	

Table 5. (con't).

Stratum	Transect Number	Transect Length (m)	Transect Area (km²)	Target Strength (dB/kg)	Sa - Area Scattering (/sr)	Total Scattering (m²/sr)	Biomass Density (Kg/m³)	Total Biomass (t/trans)	Sample Number
ST6	73	866	2.07	-36.7	0.000000	0	0.0000	0.000	
	74	789	1.89	-36.7	0.000000	0	0.0000	0.000	
Bay of	75	1439	3.45	-36.7	0.000000	0	0.0000	0.000	
Islands	76	2989	7.16	-36.7	0.000000	0	0.0000	0.000	
	77	1134	2.72	-36.7	0.000000	0	0.0000	0.000	
	78	643	1.54	-36.7	0.000000	0	0.0000	0.000	
	79	551	1.32	-36.7	0.000000	0	0.0000	0.000	
	80	3488	8.36	-36.7	0.000000	0	0.0000	0.000	
	82	2280	5.46	-36.7	0.000000	0	0.0000	0.000	
	83	3079	7.38	-36.7	0.000000	0	0.0000	0.000	
	84	10977	26.29	-36.7	0.000000	0	0.0000	0.000	
	85	2489	5.96	-36.7	0.000000	0	0.0000	0.000	
	86	2604	6.24	-36.7	0.000000	0	0.0000	0.000	
	87	9679	23.19	-36.7	0.000000	0	0.0000	0.000	
	88	1965	4.71	-36.7	0.000000	0	0.0000	0.000	
	89	14266	34.17	-36.7	0.000000	0	0.0000	0.000	
	91	14092	33.76	-36.7	0.000000	0	0.0000	0.000	
	92	1764	4.22	-36.7	0.000000	0	0.0000	0.000	
	93	2213	5.30	-36.7	0.000000	0	0.0000	0.000	
	94	2885	6.91	-36.7	0.000000	0	0.0000	0.000	
	95	3038	7.28	-36.7	0.000000	0	0.0000	0.000	
	96	4170	9.99	-36.7	0.000000	0	0.0000	0.000	
	97	4470	10.71	-36.7	0.000000	0	0.0000	0.000	
	98	7012	16.80	-36.7	0.000000	0	0.0000	0.000	
	99	6820	16.34	-36.7	0.000000	0	0.0000	0.000	
	102	8539	20.46	-36.7	0.000000	0	0.0000	0.000	
	103	9211	22.07	-36.7	0.000000	0	0.0000	0.000	
ST7	122	3438	8.10	-36.8	0.000005	41	0.0247	199.868	* 3
	123	3754	8.84	-36.8	0.000001	6	0.0033	28.825	* 3
Bonne Bay	124	2689	6.33	-36.8	0.000007	42	0.0321	203.331	* 3
	125	585	1.38	-36.8	0.000000	0	0.0000	0.000	
	126	1103	2.60	-36.8	0.000000	0	0.0000	0.000	
	127	6666	15.70	-36.8	0.000001	0	0.0000	0.000	
	128	1600	3.77	-36.8	0.000001	0	0.0000	0.000	
	129	1295	3.05	-36.8	0.000000	0	0.0000	0.000	
	130	1474	3.47	-36.8	0.000000	0	0.0000	0.000	
ST9	146	12292	92.64	-36.3	0.000010	896	0.0413	3823.298	* 5/6
	147	12399	93.44	-36.3	0.000001	93	0.0042	396.698	* 5/6
St. John's	148	10079	75.96	-36.3	0.000000	0	0.0000	0.000	
Bay	149	9937	74.89	-36.3	0.000000	8	0.0005	34.222	5/6
	150	9240	69.64	-36.3	0.000000	0	0.0000	0.000	
	151	8316	62.67	-36.3	0.000000	2	0.0001	7.367	5/6
	152	8986	67.72	-34.9	0.000000	0	0.0000	0.000	
	153	2424	18.27	-34.9	0.000006	115	0.0196	357.932	* 7
	154	3296	24.84	-34.9	0.000030	752	0.0943	2343.910	* 7
	155	5405	40.73	-34.9	0.000000	0	0.0000	0.000	
	156	13873	104.55	-34.9	0.000000	8	0.0002	24.199	7
	157	13257	99.91	-34.9	0.000000	0	0.0000	0.000	
	158	16617	125.23	-34.9	0.000000	0	0.0000	0.000	
	160	10576	79.70	-34.9	0.000000	0	0.0000	0.000	
	161	11654	87.83	-34.9	0.000001	86	0.0031	269.643	7
	162	4858	36.61	-34.9	0.000000	0	0.0000	0.000	
	163	11843	89.25	-34.9	0.000000	0	0.0000	0.000	
	164	16526	124.54	-34.9	0.000000	6	0.0002	19.999	7
	165	15273	115.10	-34.9	0.000000	7	0.0002	22.561	7
	166	14042	105.83	-34.9	0.000000	0	0.0000	0.000	
	167	6761	50.95	-34.9	0.000000	0	0.0000	0.000	

Table 6. Backscatter and biomass per transect for P423 (1991).

Stratum	Transect Number	Transect Length (m)	Transect Area (km²)	Target Strength (dB/kg)	Sa - Area Scattering (/sr)	Total Scattering (m²/sr)	Biomass Density (Kg/m²)	Total Biomass (t/trans)	Sample Number
ST4	148	8497	58.90	-36.6	0.000000	0	0.0000	0.000	
	149	8925	61.86	-36.6	0.000000	0	0.0000	0.000	
Port-au	150	10206	70.74	-36.6	0.000000	0	0.0000	0.000	
Port	152	10719	74.30	-36.6	0.000000	0	0.0000	0.000	
	154	6831	47.35	-36.6	0.000000	0	0.0000	0.000	
	155	6214	43.07	-36.6	0.000000	0	0.0000	0.000	
	156	5700	39.51	-36.6	0.000000	0	0.0000	0.000	
	158	6023	41.75	-36.6	0.000000	0	0.0000	0.000	
ST5	4	15526	83.94	-36.6	0.000000	0	0.0000	0.000	
	5	12865	69.56	-36.6	0.000000	0	0.0000	0.000	
Bay of	6	13129	70.99	-36.6	0.000000	0	0.0000	0.000	
Islands	7	11532	62.35	-36.6	0.000000	0	0.0000	0.000	
(Gulf)	15	11907	64.38	-36.6	0.000000	2	0.0002	10.106	3/18
	16	7567	40.91	-36.6	0.000000	0	0.0000	0.000	
	34	10212	55.21	-36.6	0.000000	0	0.0000	0.000	
	35	10971	59.31	-36.6	0.000000	0	0.0000	0.000	
	52	14207	76.81	-36.6	0.000013	1015	0.0601	4616.055	3/18
	53	11265	60.90	-36.6	0.000000	0	0.0000	0.000	
	54	11702	63.27	-36.6	0.000000	0	0.0000	0.000	
ST6	56	9832	17.81	-36.6	0.000000	0	0.0000	0.000	
	57	9835	17.81	-36.6	0.000000	0	0.0000	0.000	
Bonne Bay	58	9314	16.87	-36.6	0.000000	0	0.0000	0.000	
Bank	59	9393	17.01	-36.6	0.000000	0	0.0000	0.000	
	60	9829	17.80	-36.6	0.000000	0	0.0000	0.000	
	61	11115	20.13	-36.6	0.000000	0	0.0000	0.000	
	62	17510	31.72	-36.6	0.000003	101	0.0145	460.276	3/18
	63	18099	32.78	-36.6	0.000000	0	0.0000	0.000	
	64	18519	33.54	-36.6	0.000000	0	0.0000	0.000	
	90	19256	34.88	-36.6	0.000000	0	0.0000	0.000	
	91	19566	35.44	-36.6	0.000000	0	0.0000	0.000	
	92	19705	35.69	-36.6	0.000000	0	0.0000	0.000	
	93	19689	35.66	-36.6	0.000000	0	0.0000	0.000	
	94	19969	34.36	-36.6	0.000045	1533	0.2030	6972.903	* 3/18
	95	17833	32.30	-36.6	0.000696	22496	3.1689	102355.750	* 3/18
	97	15416	27.92	-36.6	0.000073	2052	0.3343	9334.772	* 3/18
	98	13091	23.71	-36.6	0.000000	0	0.0000	0.000	
	99	10172	18.42	-36.6	0.000001	17	0.0042	77.658	3/18
	100	10215	18.50	-36.6	0.000002	28	0.0069	127.777	3/18
	101	10092	18.28	-36.6	0.000000	0	0.0000	0.000	
	135	9357	16.95	-36.6	0.000000	0	0.0000	0.000	
	136	9317	16.88	-36.6	0.000000	0	0.0000	0.000	
	137	9736	17.64	-36.6	0.000000	0	0.0000	0.000	
	138	10004	18.12	-36.6	0.000004	80	0.0202	365.453	3/18
	139	10305	18.66	-36.6	0.000000	0	0.0000	0.000	
	140	10089	18.27	-36.6	0.000000	0	0.0000	0.000	
	141	8726	15.80	-36.6	0.000000	0	0.0000	0.000	
	142	9556	17.31	-36.6	0.000000	0	0.0000	0.000	
	143	12249	22.19	-36.6	0.000000	0	0.0000	0.000	
ST7	22	2132	7.23	-36.6	0.000000	0	0.0000	0.000	
	23	3472	11.78	-36.6	0.000000	0	0.0000	0.000	
Bay of	24	12342	41.88	-36.6	0.000005	198	0.0216	902.830	3/18
Islands	26	9899	33.59	-36.6	0.000000	0	0.0000	0.000	
	27	12693	43.07	-36.6	0.000000	0	0.0000	0.000	
	28	1926	6.53	-36.6	0.000000	0	0.0000	0.000	
	29	14591	49.51	-36.6	0.000000	0	0.0000	0.000	
	30	9540	32.37	-36.6	0.000000	0	0.0000	0.000	
	31	4941	16.77	-36.6	0.000000	0	0.0000	0.000	
	32	9197	31.21	-36.6	0.000000	0	0.0000	0.000	
	33	6425	21.80	-36.6	0.000000	0	0.0000	0.000	

Table 6. (con't).

Stratum	Transect Number	Transect Length (m)	Transect Area (km^2)	Target Strength (dB/kg)	Sa - Area Scattering (/sr)	Total Scattering (m^2/sr)	Biomass Density (Kg/m^3)	Total Biomass (t/trans)	Sample Number
ST8	65	1593	2.81	-36.0	0.000000	0	0.0000	0.000	
	66	2047	3.61	-36.0	0.000000	0	0.0000	0.000	
Bonne Bay	67	2345	4.13	-36.0	0.000000	0	0.0000	0.000	
	68	1931	3.40	-36.0	0.000000	0	0.0000	0.000	
	70	1817	3.20	-36.0	0.000000	0	0.0000	0.000	
	71	1059	1.87	-36.0	0.000000	0	0.0000	0.000	
	72	969	1.71	-36.0	0.000000	0	0.0000	0.000	
	74	999	1.76	-36.0	0.000000	0	0.0000	0.000	
	75	629	1.11	-36.0	0.000000	0	0.0000	0.000	
	77	2427	4.28	-36.0	0.000000	0	0.0000	0.000	
	78	2318	4.08	-36.0	0.000000	0	0.0000	0.000	
	79	2071	3.65	-36.0	0.000000	0	0.0000	0.000	
	80	2211	3.89	-36.0	0.000000	0	0.0000	0.000	
	81	2353	4.15	-36.0	0.000004	18	0.0173	71.669	* 2
	82	2765	4.87	-36.0	0.000001	4	0.0029	14.171	* 2
	83	2685	4.73	-36.0	0.000091	429	0.3614	1709.343	* 2
ST10	103	21516	115.88	-36.0	0.000000	0	0.0000	0.000	
	104	20853	112.31	-36.0	0.000000	0	0.0000	0.000	
St. John's	105	20751	111.76	-36.0	0.000000	0	0.0000	0.000	
Bay	106	21550	116.06	-36.0	0.000000	0	0.0000	0.000	
	108	17783	95.77	-36.0	0.000000	0	0.0000	0.000	
	109	11041	59.46	-36.0	0.000000	0	0.0000	0.000	
	110	11739	63.22	-36.0	0.000000	0	0.0000	0.000	
	111	12381	66.68	-36.0	0.000000	0	0.0000	0.000	
	113	13926	75.00	-36.0	0.000000	0	0.0000	0.000	
	115	17898	96.39	-36.0	0.000000	0	0.0000	0.000	
	117	5775	31.10	-36.0	0.000000	0	0.0000	0.000	
	118	4337	23.36	-36.0	0.000000	0	0.0000	0.000	
	119	13433	72.35	-36.0	0.000000	0	0.0000	0.000	
	120	8761	47.18	-36.0	0.000000	0	0.0000	0.000	
	121	7945	42.79	-36.0	0.000000	0	0.0000	0.000	
	122	5162	27.80	-36.0	0.000000	0	0.0000	0.000	
	123	24973	134.49	-36.0	0.000000	0	0.0000	0.000	
	125	7853	42.29	-36.0	0.000000	0	0.0000	0.000	
	127	8483	45.68	-36.0	0.000000	0	0.0000	0.000	
	128	9476	51.03	-36.0	0.000000	0	0.0000	0.000	
	129	8166	43.98	-36.0	0.000000	0	0.0000	0.000	
	130	14961	80.57	-36.0	0.000000	0	0.0000	0.000	
	132	15802	85.11	-36.0	0.000000	0	0.0000	0.000	

Table 7. Backscatter and biomass per transect for C452 (1993).

Stratum	Transect Number	Transect Length (m)	Transect Area (km^2)	Target Strength (dB/kg)	Sa - Area Scattering (/sr)	Total Scattering (m^2/sr)	Biomass Density (Kg/m^2)	Total Biomass (t/trans)	Sample Number
ST1	119	7690	46.66	-35.1	0.000000	0	0.0000	0.000	
	120	5335	32.37	-35.1	0.000000	0	0.0000	0.000	
Bay St.	121	4728	28.69	-35.1	0.000000	0	0.0000	0.000	
Georges	122	5225	31.70	-35.1	0.000000	0	0.0000	0.000	
(south)	123	7380	44.78	-35.1	0.000000	0	0.0000	0.000	
	124	9635	58.46	-35.1	0.000000	0	0.0000	0.000	
	125	9781	59.34	-35.1	0.000005	309	0.0169	1003.377	S4/S5
	135	9719	58.97	-35.1	0.000000	0	0.0000	0.000	
	126	10311	62.56	-35.1	0.000000	0	0.0000	0.000	
	127	13455	81.64	-35.1	0.000000	0	0.0000	0.000	
	128	13531	82.10	-35.1	0.000000	0	0.0000	0.000	
	129	13733	83.32	-35.1	0.000000	0	0.0000	0.000	
	136	4939	29.97	-35.1	0.000000	0	0.0000	0.000	
	130	13623	82.66	-35.1	0.000000	0	0.0000	0.000	
	131	13683	83.02	-35.1	0.000000	0	0.0000	0.000	
	132	15806	95.90	-35.1	0.000000	0	0.0000	0.000	
	133	15757	95.61	-35.1	0.000000	0	0.0000	0.000	
	134	16416	99.61	-35.1	0.000000	0	0.0000	0.000	
ST2	107	15528	96.34	-35.1	0.000000	0	0.0000	0.000	
	108	15225	94.46	-35.1	0.000000	0	0.0000	0.000	
Bay St.	109	15546	96.45	-35.1	0.000000	0	0.0000	0.000	
Georges	112	15720	97.53	-35.1	0.000000	0	0.0000	0.000	
(north)	113	15205	94.33	-35.1	0.000000	0	0.0000	0.000	
	114	12202	75.70	-35.1	0.000000	0	0.0000	0.000	
	115	7067	43.84	-35.1	0.000000	0	0.0000	0.000	
	116	5109	31.70	-35.1	0.000000	0	0.0000	0.000	
	117	2227	13.82	-35.1	0.000000	0	0.0000	0.000	
	118	3490	21.65	-35.1	0.000000	0	0.0000	0.000	
ST3	153	12907	73.24	-35.1	0.000000	0	0.0000	0.000	
	154	12373	70.21	-35.1	0.000000	7	0.0003	21.740	S4/S5
Port-au-	155	12023	68.22	-35.1	0.000000	0	0.0000	0.000	
Port	163	12143	68.91	-35.1	0.000000	0	0.0000	0.000	
(Gulf)	156	12784	72.54	-35.1	0.000000	0	0.0000	0.000	
	157	11746	66.65	-35.1	0.000002	112	0.0055	364.798	S4/S5
	158	12195	69.20	-35.1	0.000010	660	0.0309	2140.628	S4/S5
	159	12287	69.72	-35.1	0.000002	109	0.0051	352.575	S4/S5
	164	11884	67.43	-35.1	0.000000	0	0.0000	0.000	
	165	12181	69.12	-35.1	0.000000	0	0.0000	0.000	
	160	9001	51.08	-35.1	0.000000	0	0.0000	0.000	
	161	9005	51.10	-35.1	0.000000	0	0.0000	0.000	
	162	9375	53.20	-35.1	0.000000	0	0.0000	0.000	
ST4	139	3631	19.19	-35.1	0.000000	0	0.0000	0.000	
	141	9064	47.90	-35.1	0.000000	0	0.0000	0.000	
Port-au-	138	12689	67.06	-35.1	0.000000	0	0.0000	0.000	
Port	142	12498	66.05	-35.1	0.000000	0	0.0000	0.000	
	143	1722	9.10	-35.1	0.000000	0	0.0000	0.000	
	144	2594	13.71	-35.1	0.000000	1	0.0003	4.402	S4/S5
	145	1926	10.18	-35.1	0.000000	0	0.0000	0.000	
	146	2555	13.50	-35.1	0.000000	0	0.0000	0.000	
	147	7063	37.32	-35.1	0.000000	0	0.0000	0.000	
	148	8353	44.14	-35.1	0.000000	0	0.0000	0.000	
	149	1657	8.76	-35.1	0.000000	0	0.0000	0.000	
	150	5763	30.46	-35.1	0.000000	0	0.0000	0.000	
	151	5609	29.64	-35.1	0.000000	0	0.0000	0.000	
	152	7644	40.40	-35.1	0.000000	0	0.0000	0.000	
ST5	1	12243	52.89	-35.1	0.000000	0	0.0000	0.000	
	2	8975	38.77	-35.1	0.000000	0	0.0000	0.000	
Bay of	3	11555	49.92	-35.1	0.000000	4	0.0002	12.343	S4/S5
Islands	4	10044	43.39	-35.1	0.000000	0	0.0000	0.000	
(Gulf)	5	12413	53.62	-35.1	0.000000	26	0.0015	82.897	S4/S5
	6	9656	41.71	-35.1	0.000000	0	0.0000	0.000	
	7	10180	43.98	-35.1	0.000000	0	0.0000	0.000	
	8	9935	42.92	-35.1	0.000000	0	0.0000	0.000	
	9	9014	38.94	-35.1	0.000000	0	0.0000	0.000	
	11	11925	51.51	-35.1	0.000001	55	0.0035	177.957	S4/S5
	13	10056	43.44	-35.1	0.000001	45	0.0034	146.911	S4/S5
	14	8391	36.25	-35.1	0.000012	442	0.0396	1435.066	S4/S5
	16	7868	33.99	-35.1	0.000019	632	0.0603	2050.567	S4/S5
	17	8141	35.17	-35.1	0.000014	490	0.0452	1589.474	S4/S5
	18	12435	53.72	-35.1	0.000012	662	0.0400	2149.016	S4/S5
	19	10976	47.42	-35.1	0.000013	631	0.0432	2046.864	S4/S5

Table 7. (con't).

Stratum	Transect Number	Transect Length (m)	Transect Area (km²)	Target Strength (dB/kg)	Sa - Area Scattering (/sr)	Total Scattering (m²/sr)	Biomass Density (Kg/m²)	Total Biomass (t/trans)	Sample Number
ST6	23	9322	21.19	-35.9	0.000008	176	0.0324	686.548	56
	24	9574	21.77	-35.9	0.000005	114	0.0204	444.292	56
Bonne Bay	26	10862	24.70	-35.9	0.000001	34	0.0053	131.371	56
Bank	27	8348	18.98	-35.9	0.000004	82	0.0169	319.967	56
	30	8939	20.33	-35.9	0.000011	231	0.0442	899.189	* 56
	31	12251	27.86	-35.9	0.000018	491	0.0686	1911.771	56
	32	14030	31.90	-35.9	0.000005	166	0.0190	606.647	56
	33	15425	35.07	-35.9	0.000005	167	0.0185	649.906	56
	34	16865	38.35	-35.9	0.000004	157	0.0159	610.748	56
	35	16374	37.23	-35.9	0.000002	84	0.0088	325.903	56
	45	18309	41.63	-35.8	0.000014	592	0.0544	2265.905	S7/S8
	46	19717	44.83	-35.8	0.000005	219	0.0187	838.293	S7/S8
	47	17239	39.20	-35.8	0.000009	358	0.0349	1369.321	S7/S8
	48	16289	37.04	-35.8	0.000004	148	0.0153	564.938	S7/S8
	50	18050	41.04	-35.8	0.000057	2337	0.2178	8939.599	* S7/S8
	51	17604	39.87	-35.8	0.000048	1891	0.1828	7234.012	* S7/S8
	52	13165	29.93	-35.8	0.000000	0	0.0000	0.000	
	53	11357	25.82	-35.8	0.000000	3	0.0004	11.280	S7/S8
	54	11476	26.09	-35.8	0.000000	0	0.0000	0.000	
	55	8529	19.39	-35.8	0.000003	87	0.0113	318.933	S7/S8
	77	6491	14.76	-36.3	0.000000	0	0.0000	0.000	
	78	6162	14.01	-36.3	0.000026	366	0.1102	1544.584	S9
	80	6402	14.96	-36.3	0.000023	340	0.0986	1435.055	S9
	81	9484	12.47	-36.3	0.000026	323	0.1094	1364.748	S9
	82	9142	11.69	-36.3	0.000044	518	0.1869	2184.906	S9
	83	6621	15.05	-36.3	0.000018	270	0.0758	1141.157	S9
	84	7705	17.52	-36.3	0.000017	305	0.0734	1286.716	S9
	85	6408	14.57	-36.3	0.000031	455	0.1318	1921.008	S9
	86	4851	11.03	-36.3	0.000050	554	0.2122	2340.579	S9
	87	6764	15.38	-36.3	0.000004	60	0.0165	254.088	* S9
	88	5502	12.51	-36.3	0.000020	245	0.0827	1034.815	S9
	89	5890	13.39	-36.3	0.000029	389	0.1227	1642.771	S9
	90	5356	12.18	-36.3	0.000004	46	0.0161	196.299	S9
	91	8715	19.82	-36.3	0.000000	6	0.0014	27.012	S9
	92	7894	17.95	-36.3	0.000006	106	0.0249	447.665	S9
	93	8524	19.38	-36.3	0.000001	14	0.0030	57.797	S9
	94	8289	18.85	-36.3	0.000001	28	0.0062	116.456	S9
	95	10058	22.87	-36.3	0.000009	197	0.0364	831.463	S9
	96	8092	18.40	-36.3	0.000010	177	0.0407	748.091	S9
	98	11728	26.67	-36.3	0.000011	286	0.0453	1206.816	S9
	99	11627	26.44	-36.3	0.000008	202	0.0322	852.529	S9
	100	10418	23.69	-36.3	0.000009	221	0.0393	931.530	S9
	101	8411	19.15	-36.3	0.000002	32	0.0072	136.955	S9
	102	9238	21.23	-36.3	0.000005	116	0.0231	491.115	S9
ST7	37	14118	72.48	-35.1	0.000007	508	0.0227	1647.843	S4/S5
	39	11058	56.77	-35.1	0.000000	0	0.0000	0.000	
Bay of	40	12281	63.05	-35.1	0.000000	0	0.0000	0.000	
Islands	41	11434	58.70	-35.1	0.000000	0	0.0000	0.000	
	42	1135	5.82	-35.1	0.000000	0	0.0000	0.000	
	43	2706	13.89	-35.1	0.000000	0	0.0000	0.000	
	44	4874	25.02	-35.1	0.000000	0	0.0000	0.000	
ST8	57	2449	5.32	-35.8	0.000000	0	0.0000	0.000	
	58	2847	6.18	-35.8	0.000003	19	0.0115	71.366	S7/S8
Bonne Bay	60	2021	4.39	-35.8	0.000006	26	0.0224	98.427	S7/S8
	61	2323	5.48	-35.8	0.000000	0	0.0000	0.000	
	62	2500	5.43	-35.8	0.000000	0	0.0000	0.000	
	63	306	0.67	-35.8	0.000000	0	0.0000	0.000	
	64	1833	3.98	-35.8	0.000000	0	0.0000	0.000	
	65	1793	3.89	-35.8	0.000000	0	0.0000	0.000	
	67	2047	4.44	-35.8	0.000000	0	0.0000	0.000	
	69	2034	4.42	-35.8	0.000000	0	0.0000	0.000	
	71	2060	4.47	-35.8	0.000001	4	0.0032	14.105	S7/S8
	73	2099	4.56	-35.8	0.000000	0	0.0000	0.000	

Table 8. Backscatter and biomass per strata for P392 (1989).

Stratum	Target Strength (dB/kg)	Stratum Area (km²)	Area Scattering (/sr)	Total Scattering (m²/sr) Total	S.E.	Biomass Density (kg/m³)	Total Biomass (t/stratum) Total	S.E.	C.V.
ST1	-32.9	444.90	0.000000	0	0	0.0000	0	0	
ST2	-36.7	1157.35	0.000000	51	41	0.0002	236	191	
ST3	-36.7	665.81	0.000000	0	0	0.0000	0	0	
ST5	-36.7	2180.53	0.000000	892	685	0.0019	4154	3190	
ST6	-36.7	295.73	0.000000	0	0	0.0000	0	0	
ST7	-36.8	53.24	0.000002	89	54	0.0081	432	263	
ST9	-35.7	1640.29	0.000001	1973	1128	0.0045	7380	4340	
Total		6437.85	0.000003	3005	1321	0.0019	12202	5396	.45

Table 9. Backscatter and biomass per strata for P423 (1991).

Stratum	Target Strength (dB/kg)	Stratum Area (km²)	Area Scattering (/sr)	Total Scattering (m²/sr) Total	S.E.	Biomass Density (kg/m³)	Total Biomass (t/stratum) Total	S.E.	C.V.
ST4	-36.6	437.49	0.000000	0	0	0.0000	0	0	
ST5	-36.6	707.63	0.000001	1017	1014	0.0065	4626	4615	
ST6	-36.6	682.47	0.000039	26307	22500	0.1754	119695	102373	
ST7	-36.6	295.73	0.000001	198	198	0.0031	903	903	
ST8	-36.0	53.24	0.000008	451	420	0.0337	1795	1705	
ST10	-36.0	1640.28	0.000000	0	0	0.0000	0	0	
Total		3816.84	0.000049	27973	24140	0.0333	127019	102495	.81
Spring							70061		
Autumn							56958		

Table 10. Backscatter and biomass per strata for C452 (1993).

Stratum	Target Strength (dB/kg)	Stratum Area (km²)	Area Scattering (/sr)	Total Scattering (m²/sr) Total	S.E.	Biomass Density (kg/m³)	Total Biomass (t/stratum) Total	S.E.	C.V.
ST1	-35.1	1157.35	0.000000	309	309	0.0009	1003	1003	
ST2	-35.1	665.82	0.000000	0	0	0.0000	0	0	
ST3	-35.1	850.62	0.000001	887	658	0.0034	2880	2134	
ST4	-35.1	437.40	0.000000	1	1	0.0000	4	4	
ST5	-35.1	707.63	0.000004	2987	1093	0.0137	9691	3546	
ST6	-36.0	1035.49	0.000012	12554	2901	0.0485	50223	11145	
ST7	-35.1	295.73	0.000002	508	508	0.0056	1648	1648	
ST8	-35.8	53.24	0.000001	48	30	0.0035	184	115	
Total		5203.28	0.000020	17294	3225	0.0126	65633	12045	.18
Spring							31002		
Autumn							34631		

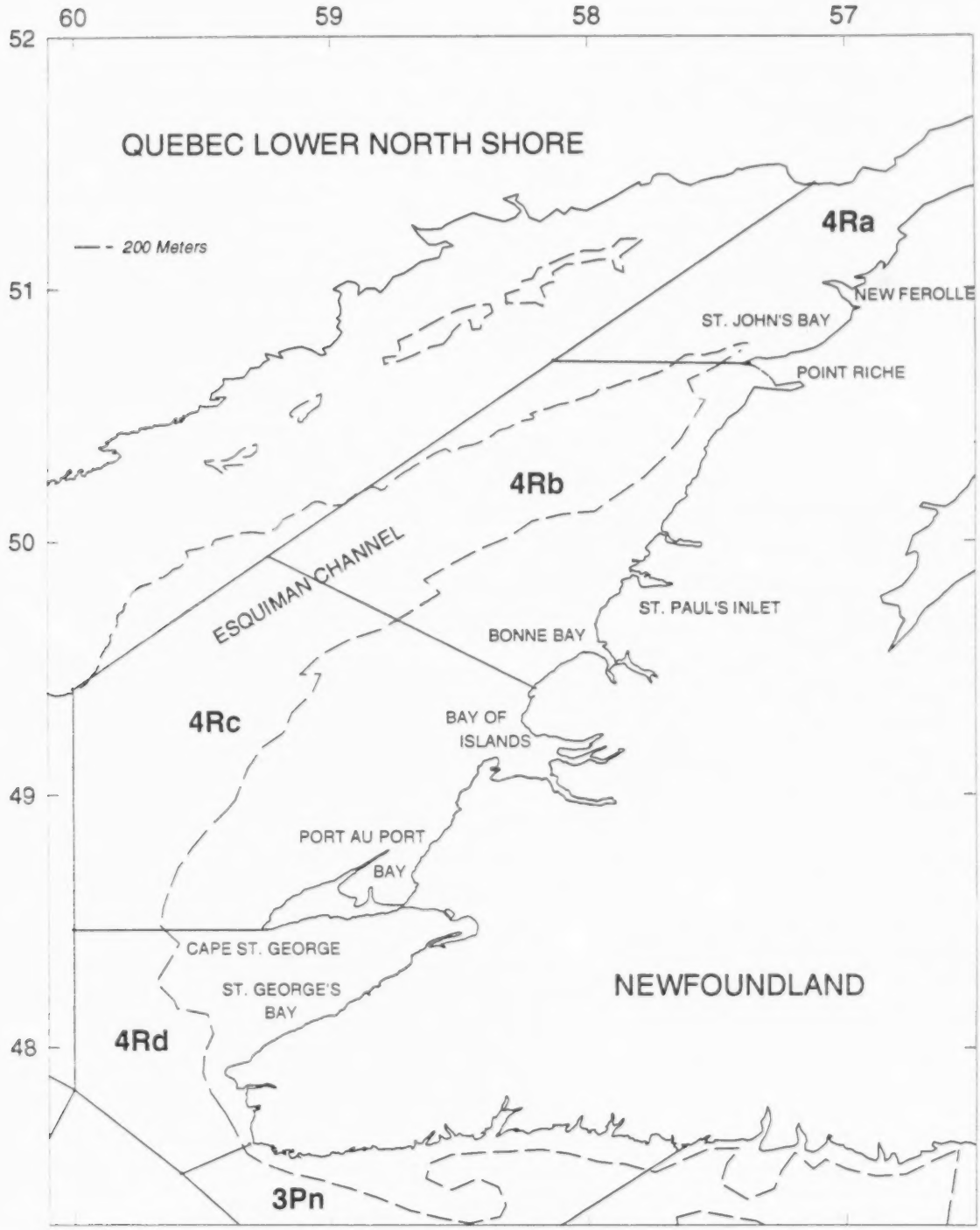

Figure 1. Northeastern Gulf of St. Lawrence

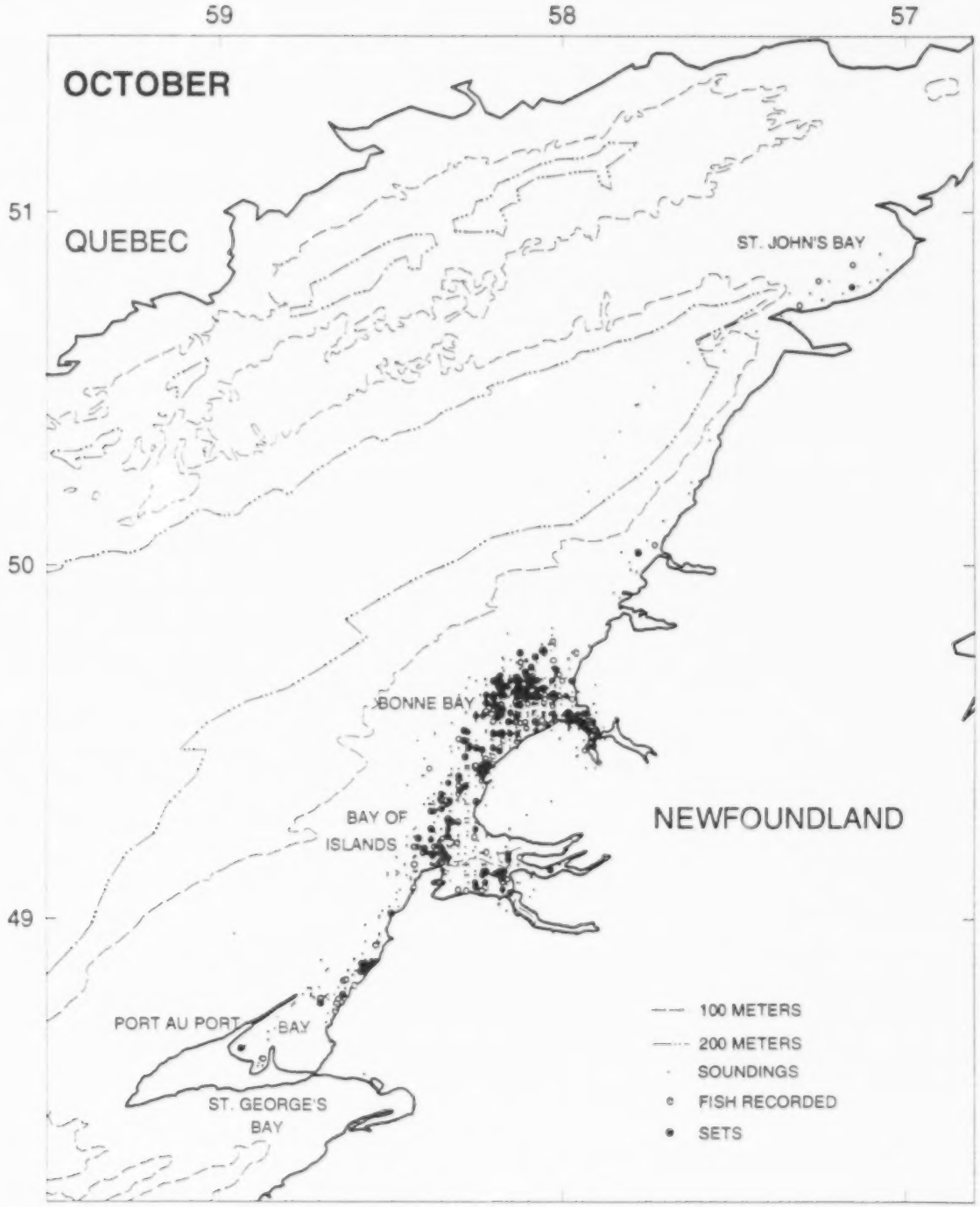

Figure 2. Position (½ h intervals) of sonar observations (soundings), of herring school detections (fish recorded) and of successful fishing sets (sets) made from two purse seiners during October from 1982 to 1987.

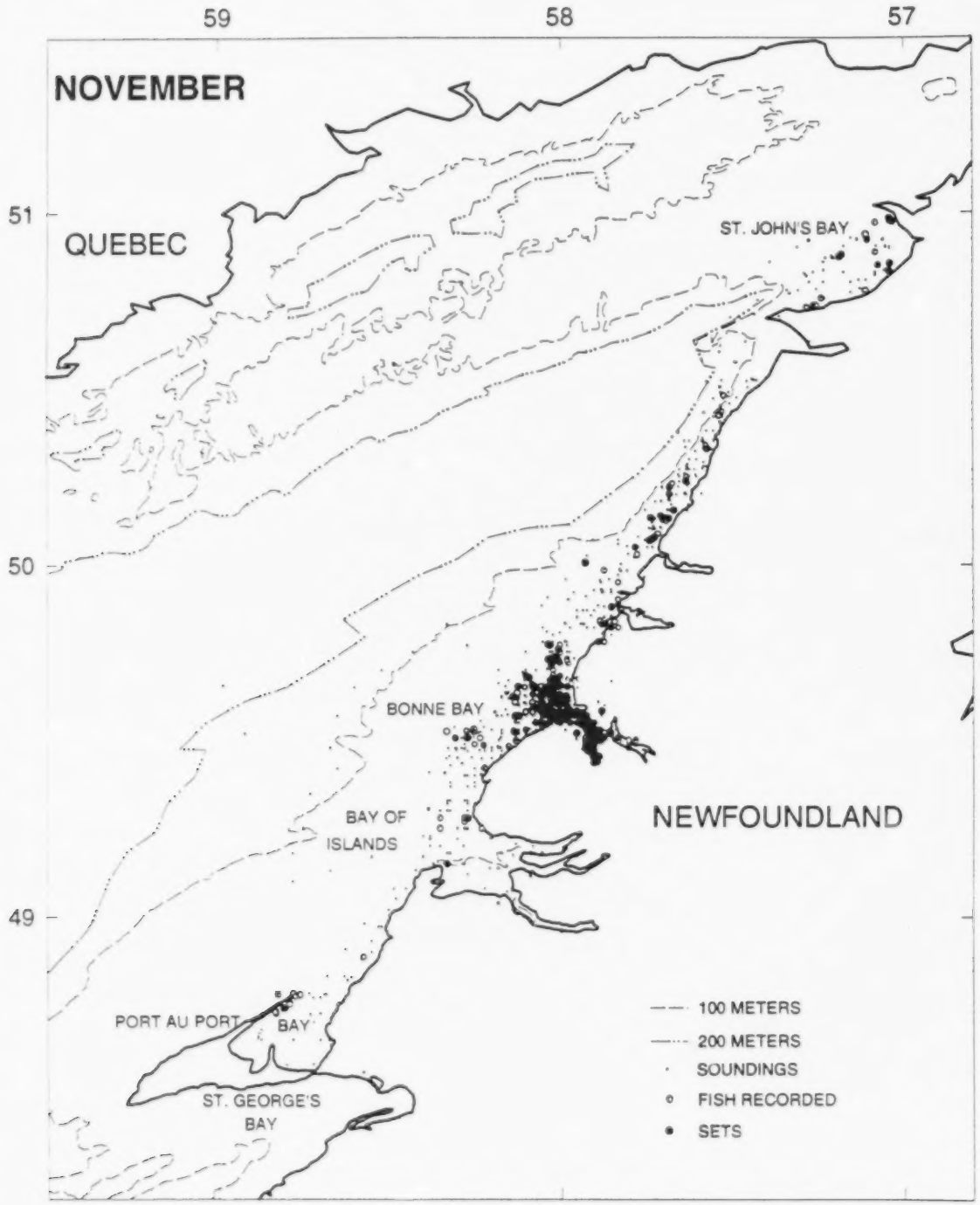

Figure 3. Position (½ h intervals) of sonar observations (soundings), of herring school detections (fish recorded) and of successful fishing sets (sets) made from two purse seiners during November from 1982 to 1987.

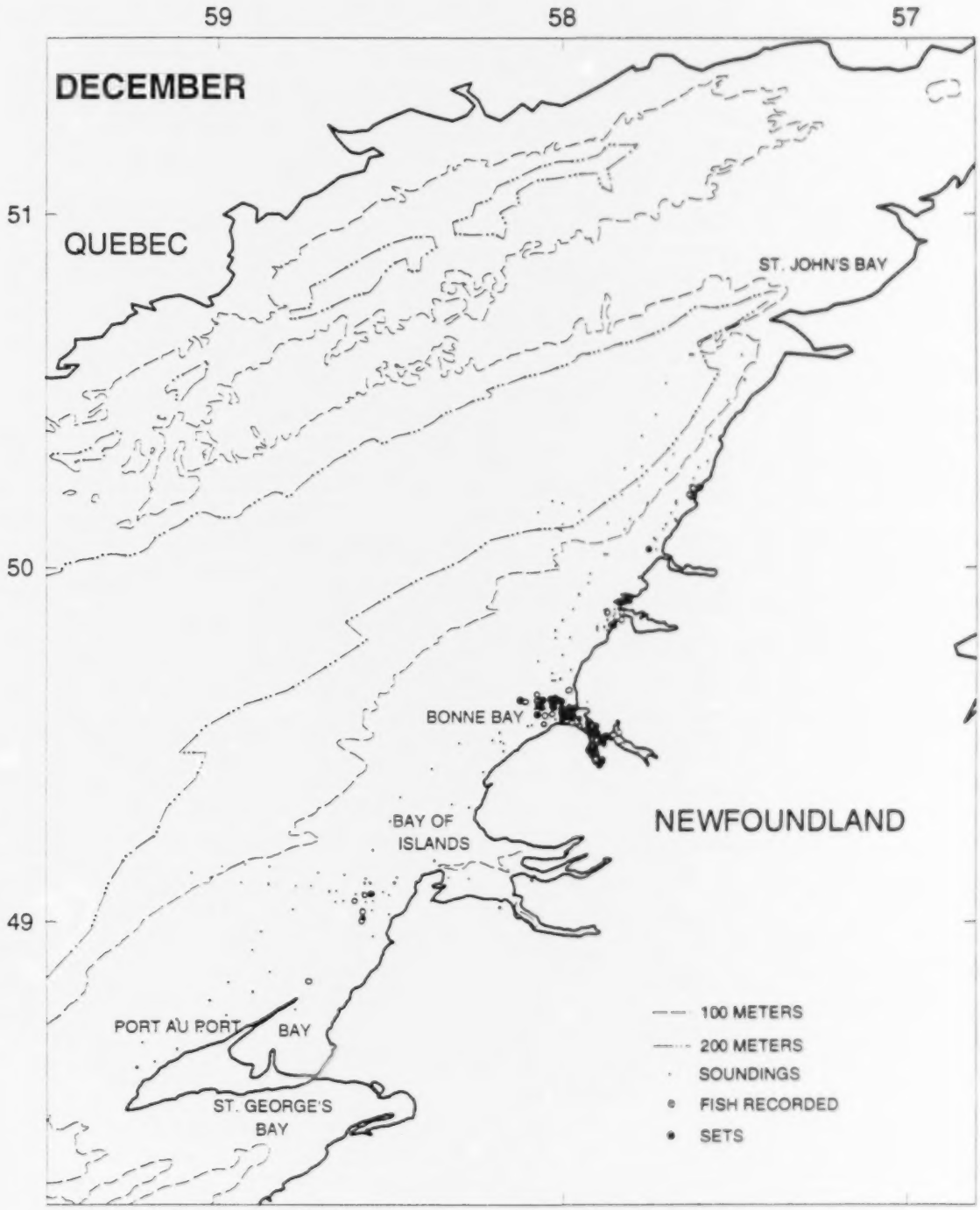

Figure 4. Position (½ h intervals) of sonar observations (soundings), of herring school detections (fish recorded) and of successful fishing sets (sets) made from two purse seiners during December from 1982 to 1987.

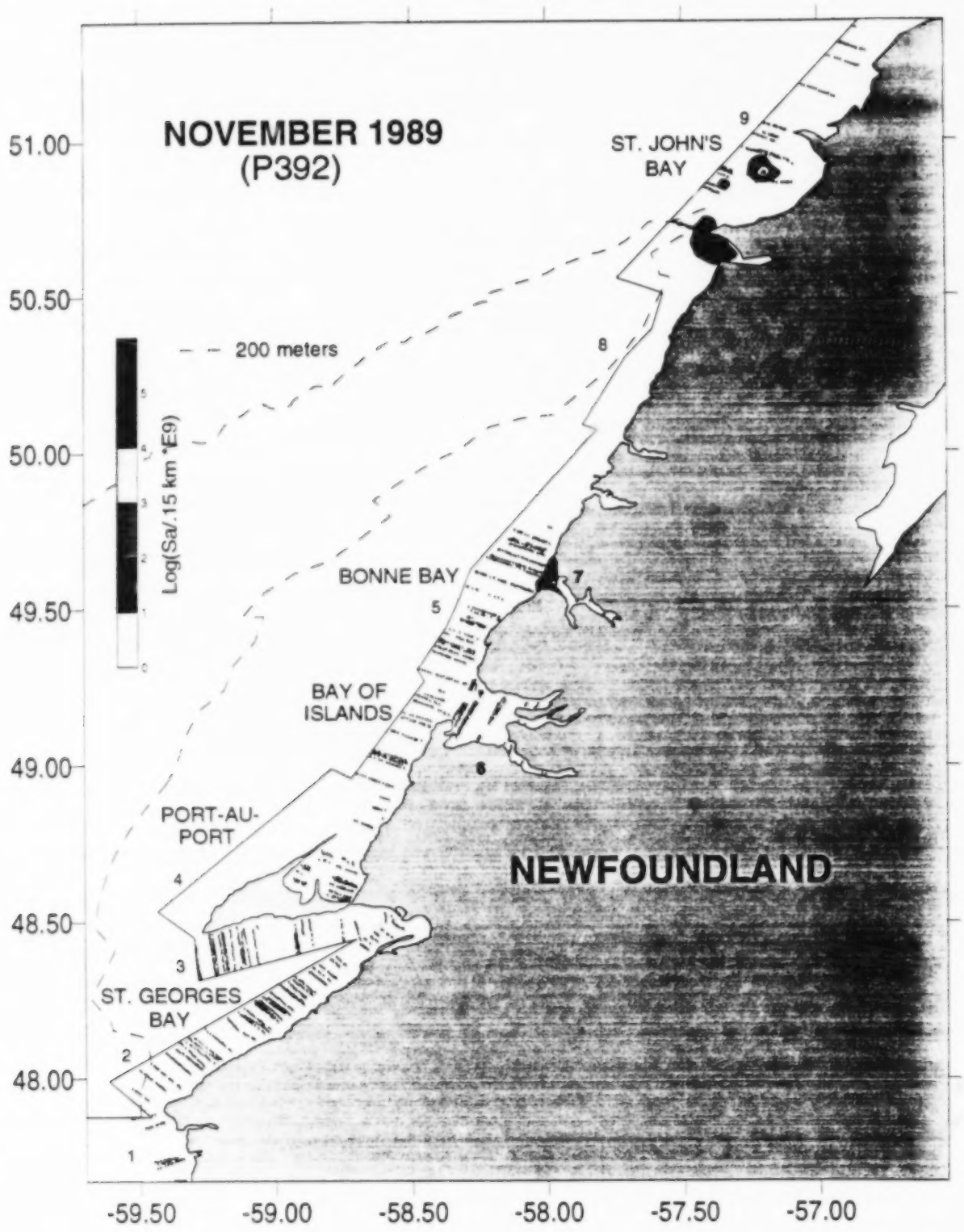

Figure 5. Distribution of acoustic backscatter from herring schools along the west coast of Newfoundland in November, 1989 (stratum numbers and completed transects are indicated).

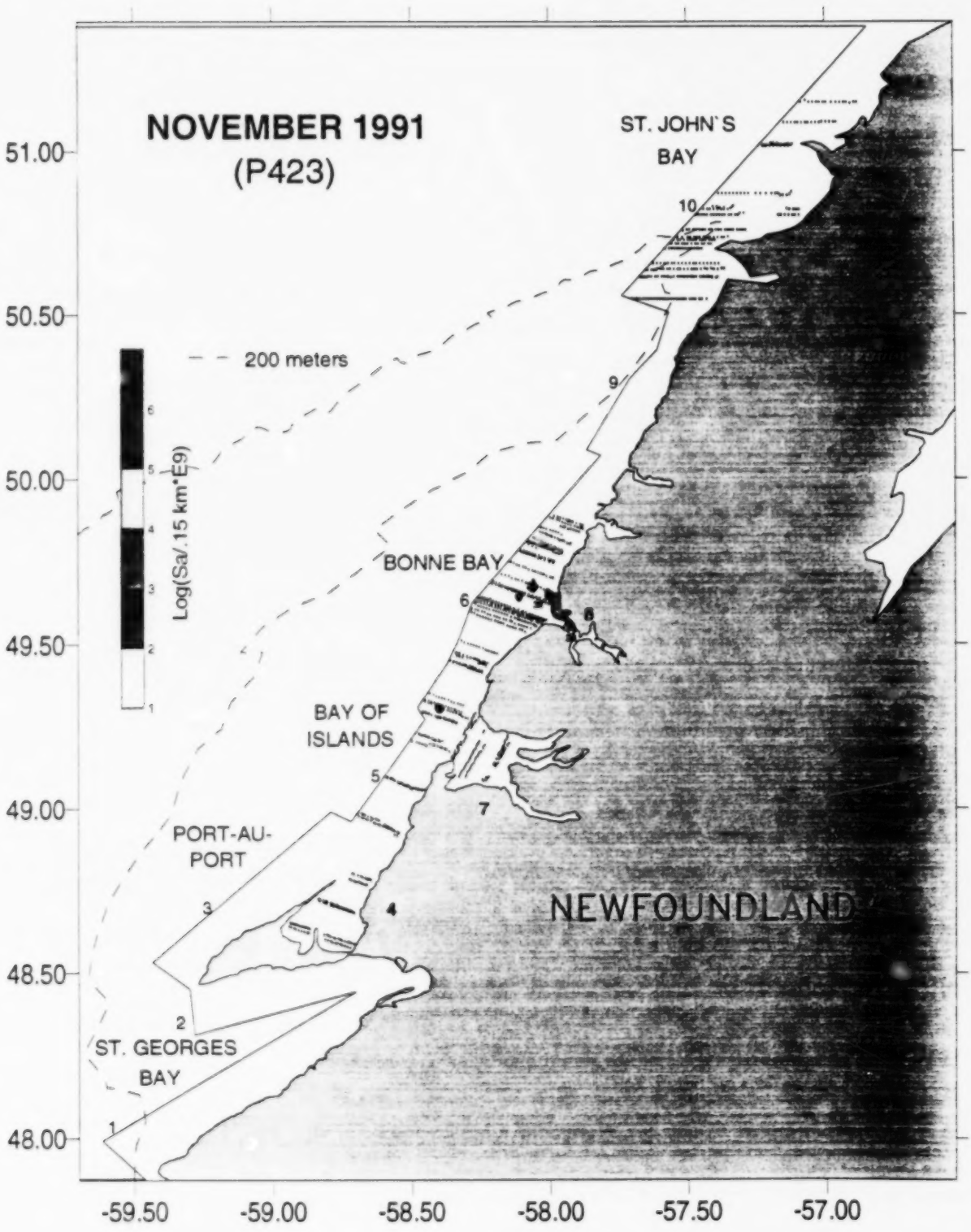

Figure 6. Distribution of acoustic backscatter from herring schools along the west coast of Newfoundland in November, 1991 (stratum numbers and completed transects are indicated).

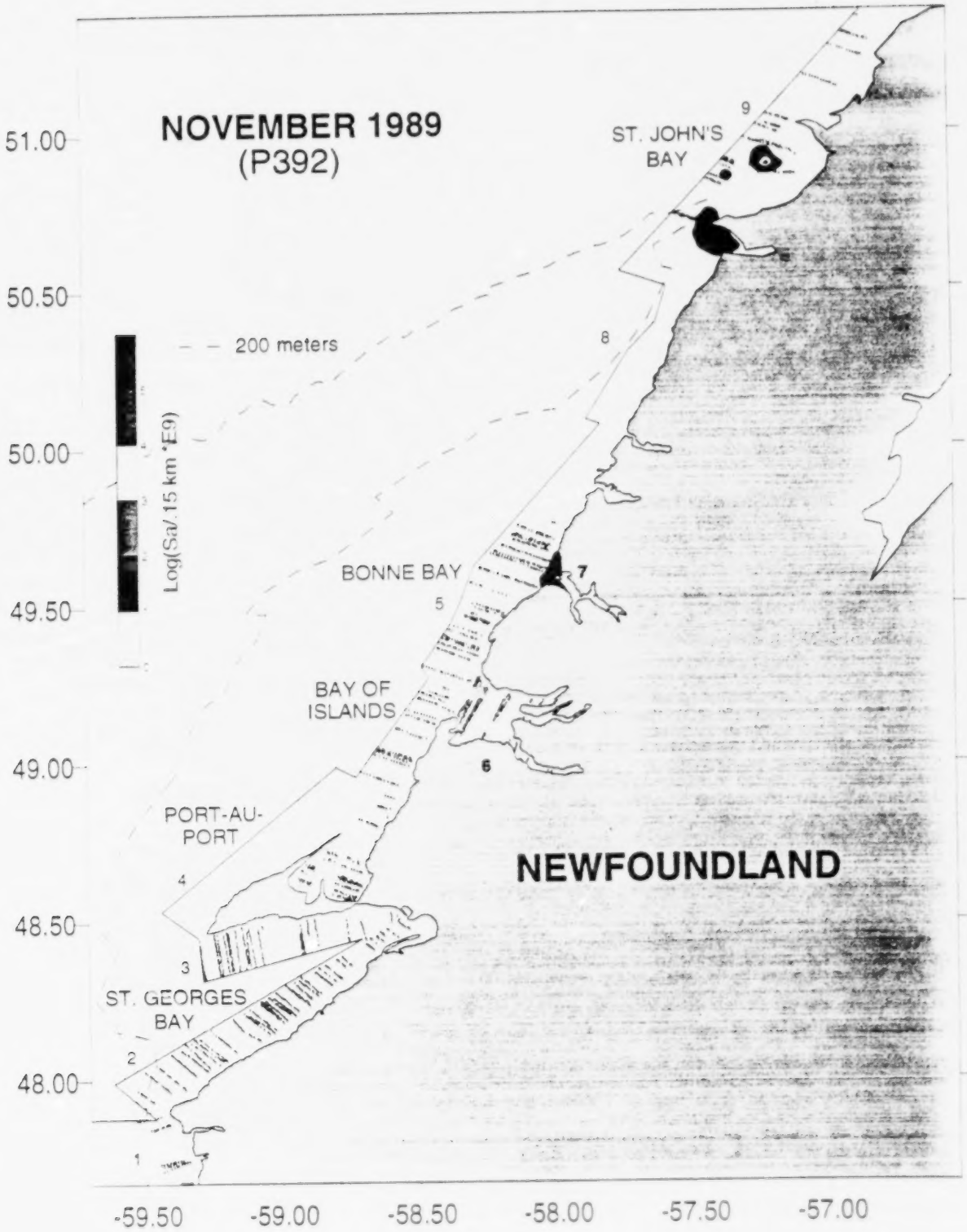

Figure 5. Distribution of acoustic backscatter from herring schools along the west coast of Newfoundland in November, 1989 (stratum numbers and completed transects are indicated).

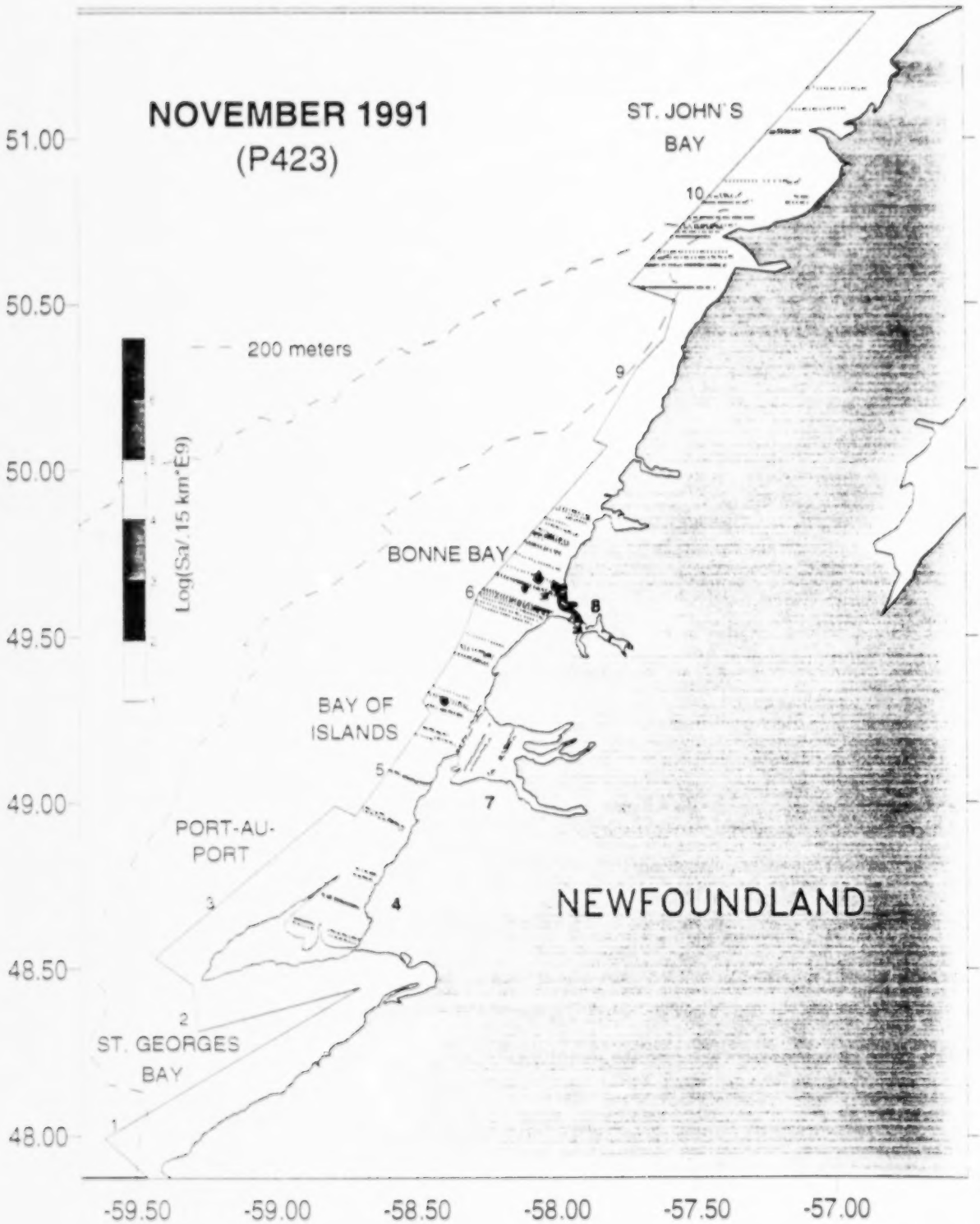

Figure 6. Distribution of acoustic backscatter from herring schools along the west coast of Newfoundland in November 1991 (stratum numbers and completed transects are indicated).

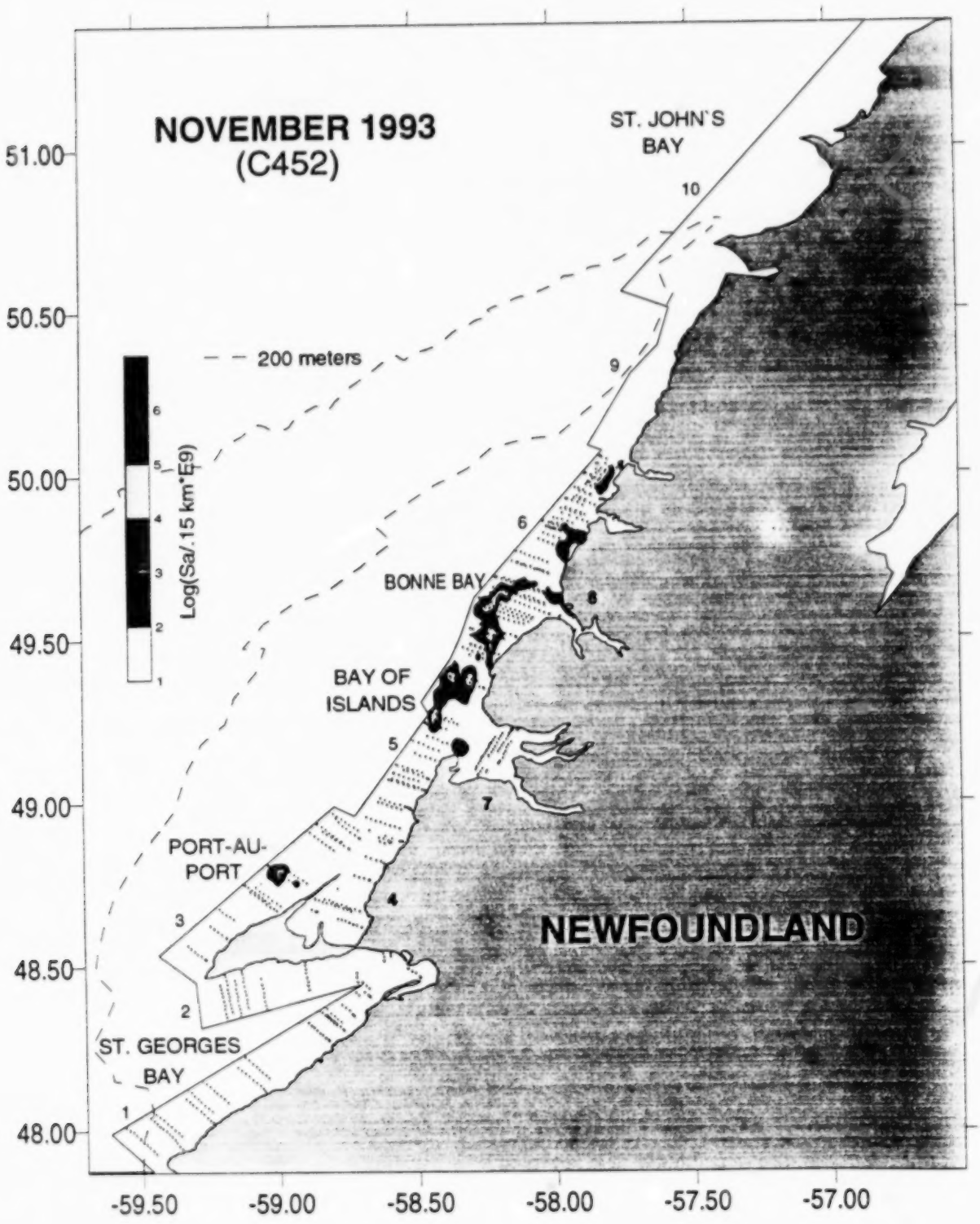

Figure 7. Distribution of acoustic backscatter from herring schools along the west coast of Newfoundland in November, 1993 (stratum numbers and completed transects are indicated).

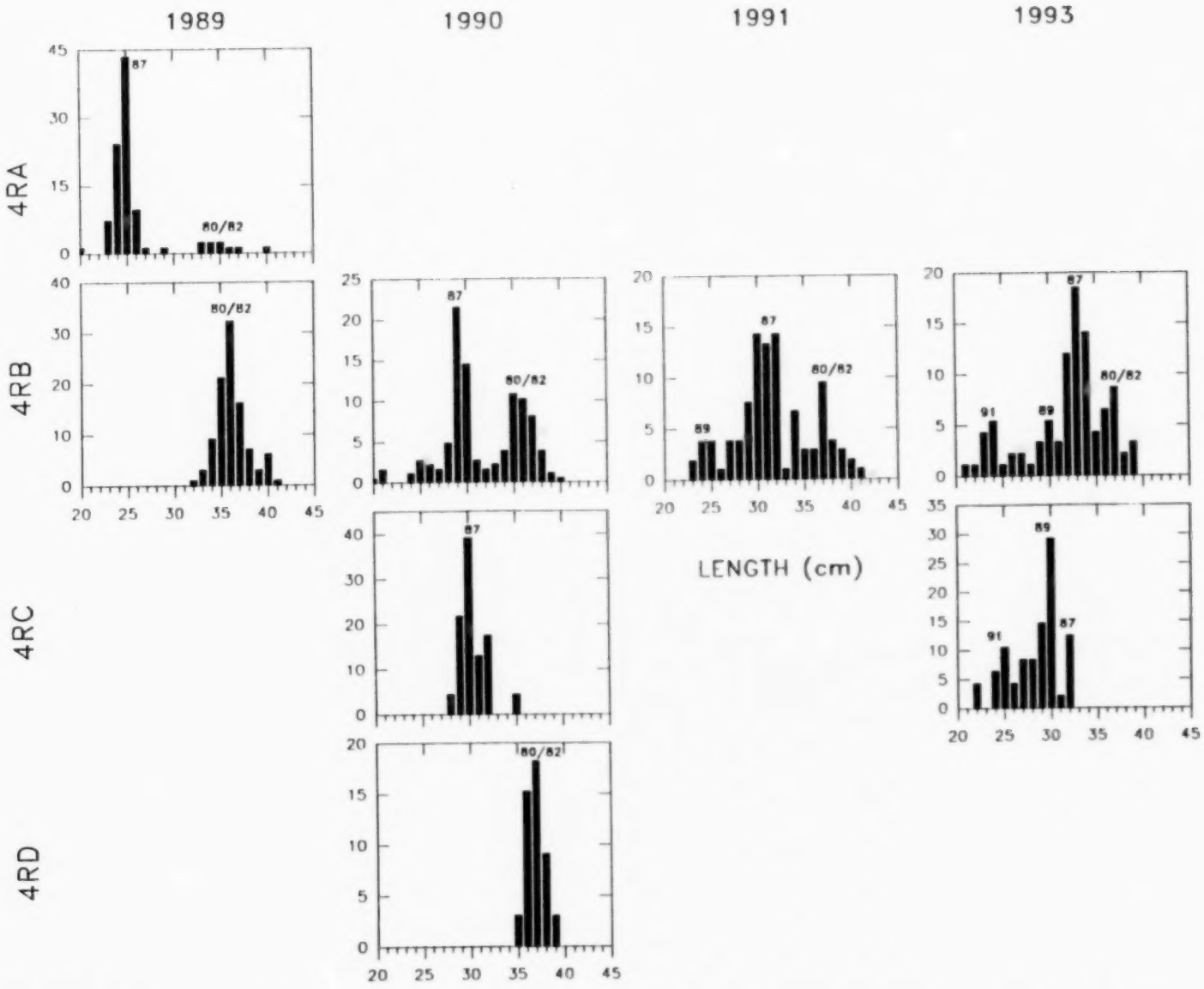

Figure 8. Length frequency distributions of spring–spawning herring from the late fall hydroacoustic surveys in subareas 4Ra to 4Rd from 1989 to 1993 (major year–classes are indicated).

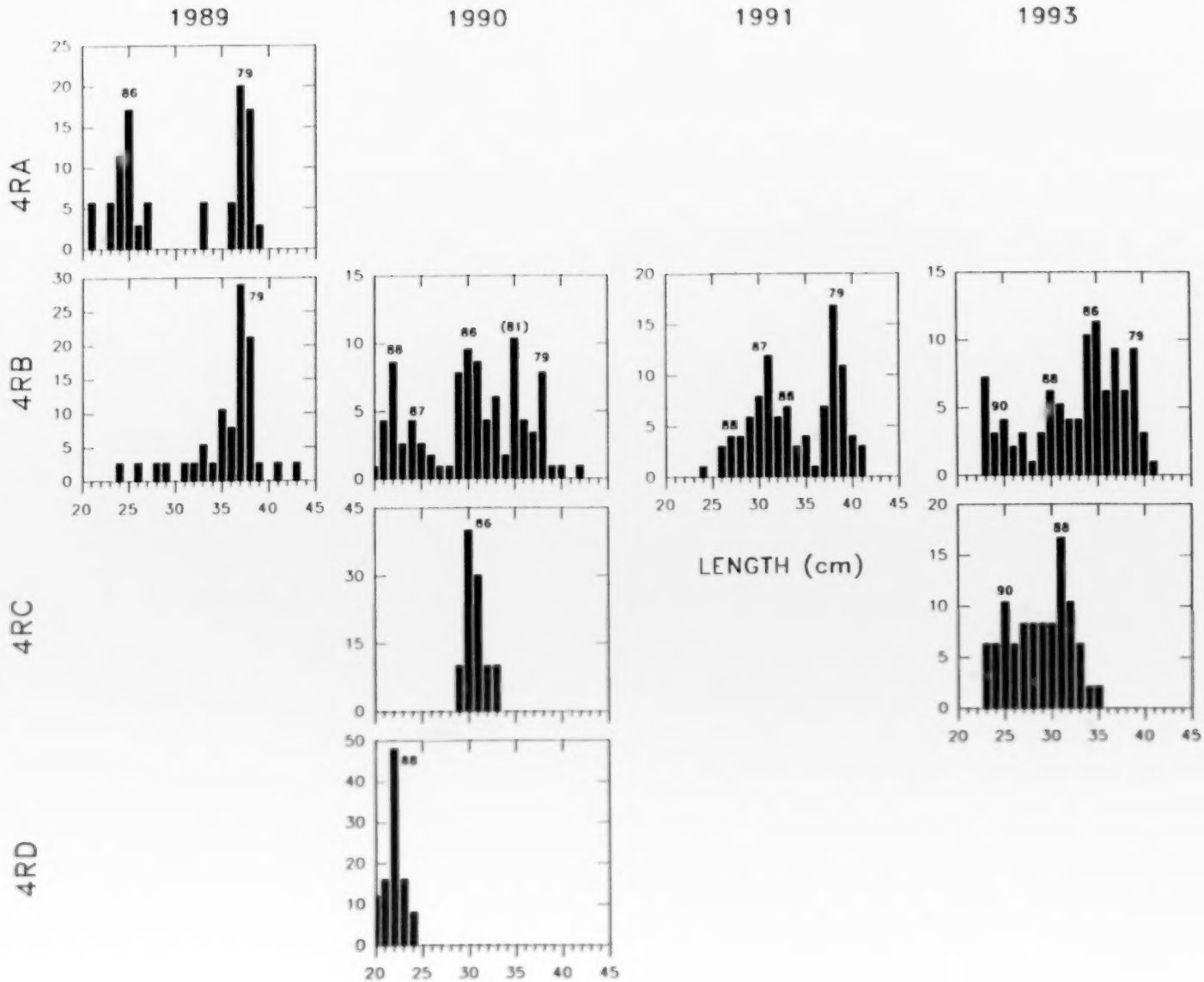

Figure 9. Length frequency distributions of autumn-spawning herring from the late fall hydroacoustic surveys in subareas 4Ra to 4Rd from 1989 to 1993 (major year-classes are indicated).